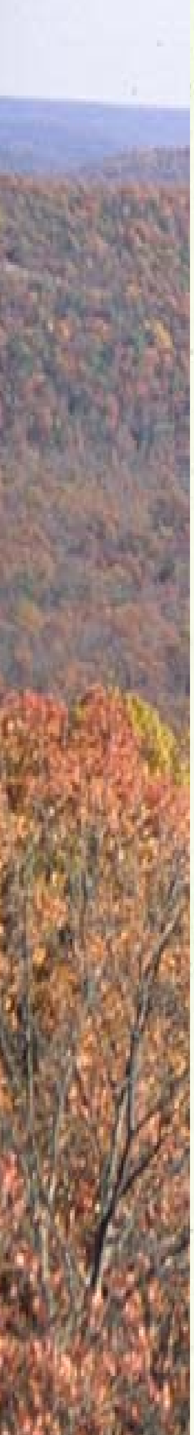
Simulating Landscape Changes Due to

- habitat succession,
- natural disturbance events,
- and management

… and predicting impacts on birds

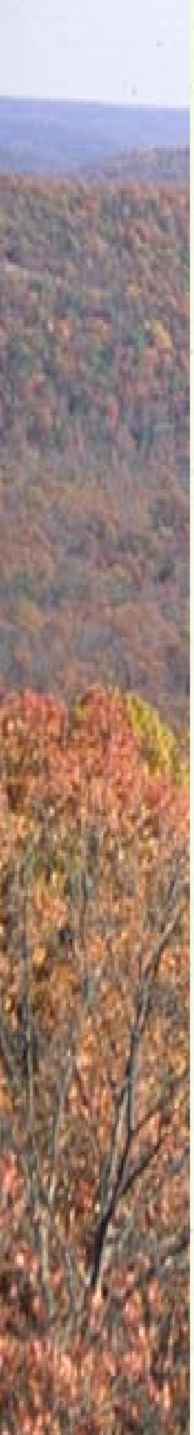
Steve Shifley and Frank Thompson

North Central Research Station



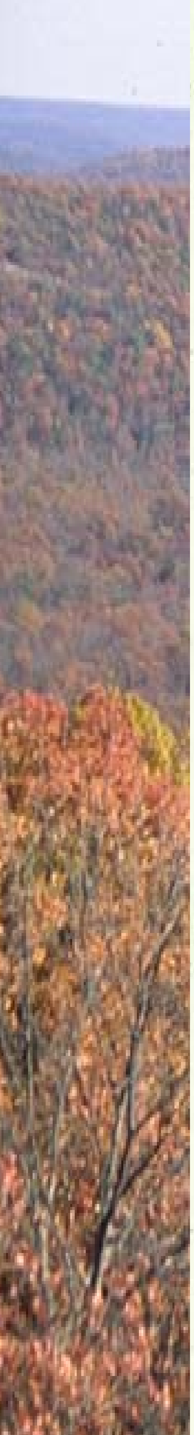
Outline

- Assumptions
- The issues of scale and detail
- Classes of models
- Pro and Cons
- Example application



Focus on how disturbance affects forest landscapes

- How does a specific landscape change in response to disturbance over time
  - *Harvest, fire, wind, herbivory, land use change*
- Attributes of interest include
  - *Vegetation composition & structure*
  - *Wildlife population size or habitat quality*
  - *Economic value*
  - *Aesthetic Quality*
  - *Water Quality*
- How are those changes spatially arranged?
- How do those changes affect policy and decision making?



Working across multiple scales

Trees vs. Wildlife vs. Everything else

Our problem was to find a means to predict forest structure and composition in a spatially-explicit model capable of tracking the location of disturbance events, linking disturbances to the specific forest vegetation communities affected, and predicting how the forest vegetation, wildlife, and other attributes will change over time.

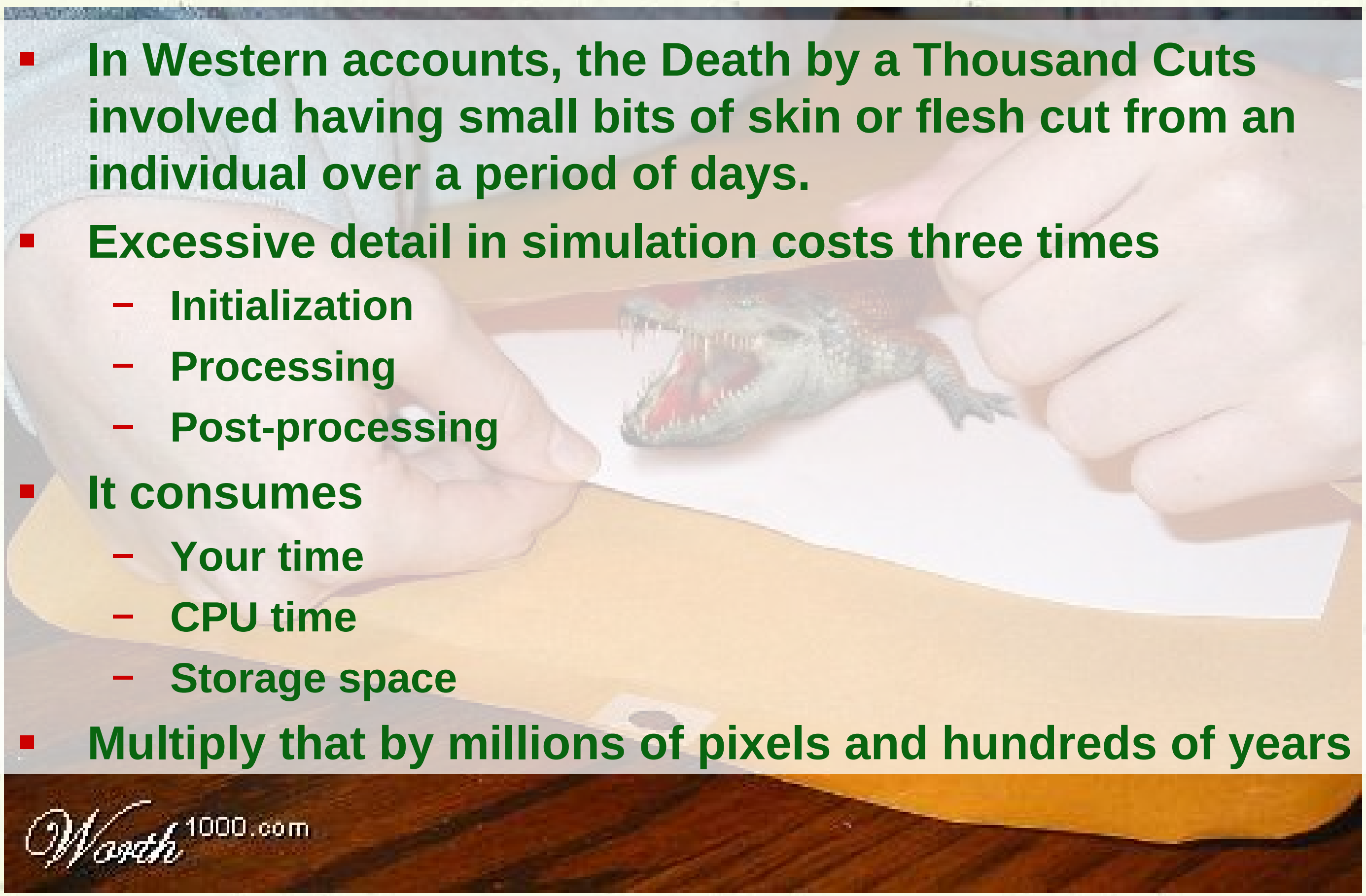
Essentially this amounted to creating a dynamic map of predicted forest vegetation composition and structure through time …and linking wildlife and other attributes to that.

Scale and Detail

- For wildlife modeling, figure out what you ***<u>need</u>*** to know about the landscape and its vegetation vs. what you'd like to know.
- Understand the range of models available and their limitations.
- Settle on the best available of all the inadequate choices.

- Weigh requirements carefully.

There is a huge cost associated with requiring too much detail in a model. “Death by 1,000 cuts”

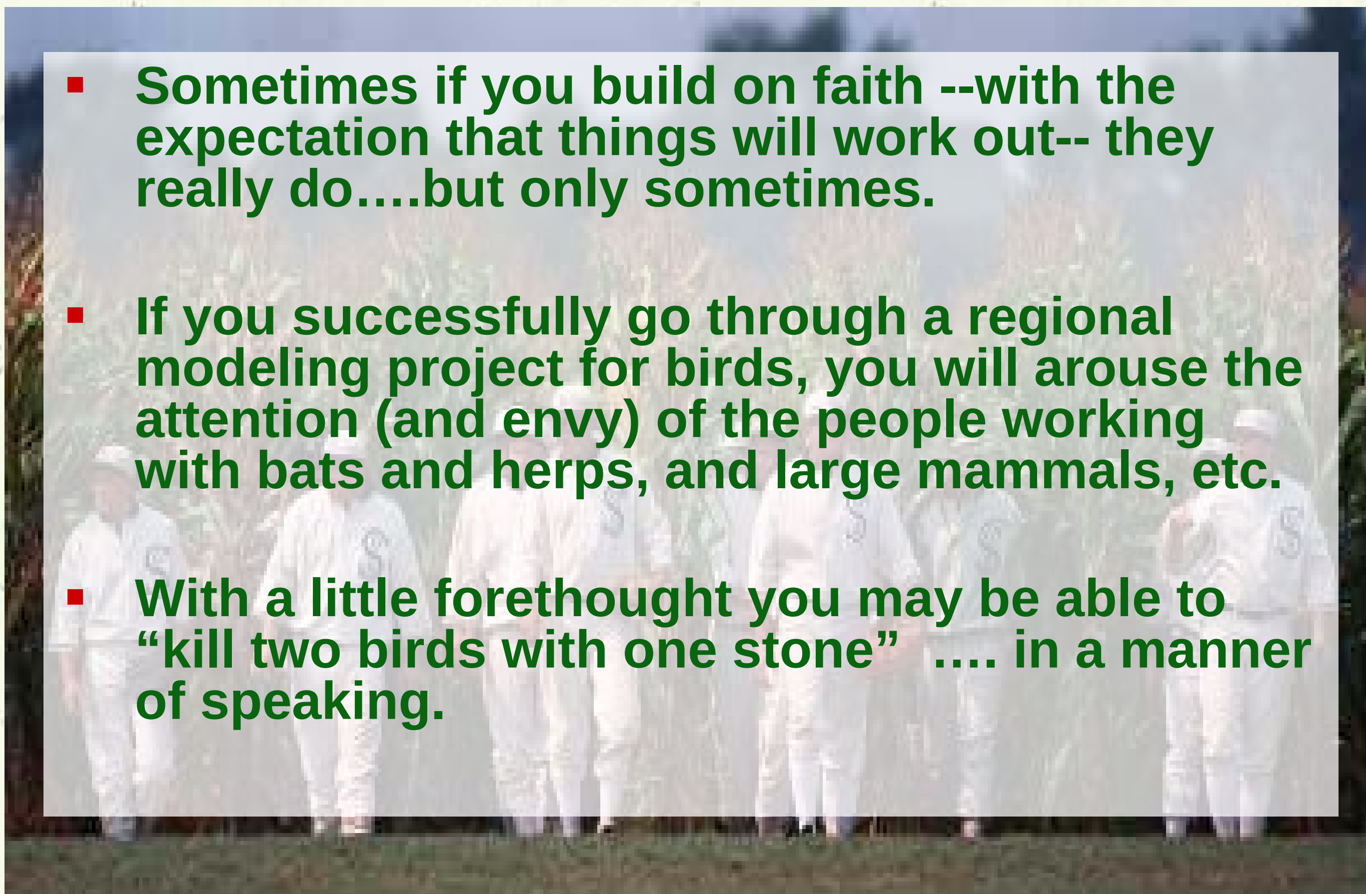


- **In Western accounts, the Death by a Thousand Cuts involved having small bits of skin or flesh cut from an individual over a period of days.**
- **Excessive detail in simulation costs three times**
  - **Initialization**
  - **Processing**
  - **Post-processing**
- **It consumes**
  - **Your time**
  - **CPU time**
  - **Storage space**
- **Multiply that by millions of pixels and hundreds of years**

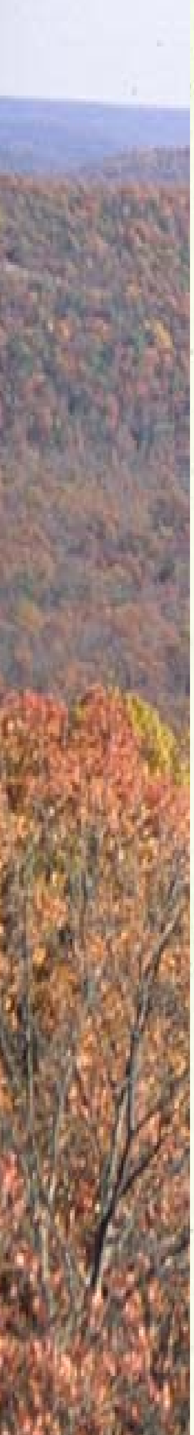
Those paper cuts scare me half to death.

But there is also a huge cost associated with failure to anticipate future options “Build it and they will come”

- **Sometimes if you build on faith --with the expectation that things will work out-- they really do….but only sometimes.**
- **If you successfully go through a regional modeling project for birds, you will arouse the attention (and envy) of the people working with bats and herps, and large mammals, etc.**
- **With a little forethought you may be able to “kill two birds with one stone” …. in a manner of speaking.**

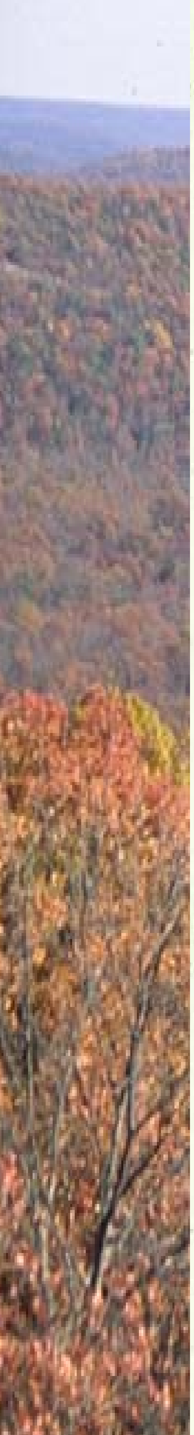


Field of Dreams



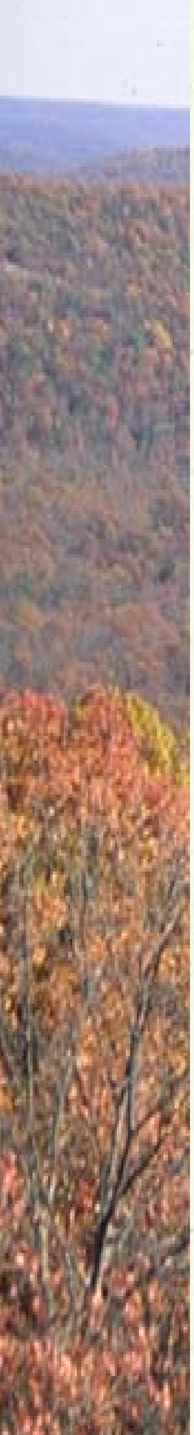
Scale and Detail

- In theory we could just use tree- or stand-level data, simulate change, and aggregate that to get landscape scale inference.
- Maybe someday that will work.
- Currently we have
  - Spatial gaps in stand-level data
  - Limited computational capacity
  - Limited data storage capacity
  - Limited hours in the day
- So there are discrete approaches that vary with spatial and temporal scale



Spatial and Temporal Scale

- Stand (2 to 50 ha, 1 to 50+ years)
- Compartment (100 to 10,000 ha; 10 to 100+ years)
  - Multiple Stands
  - Typically one owner
  - Often all forested
- Landscape (1,000 to 1,000,000+ ha, 50 to 100+ yrs)
  - Multiple owners
  - Mixed land cover
- Ecoregion(s) (Millions of ha, 50 to 100+ yrs)
  - Mega landscape
  - Mixed land cover
  - Multiple owners
  - High diversity



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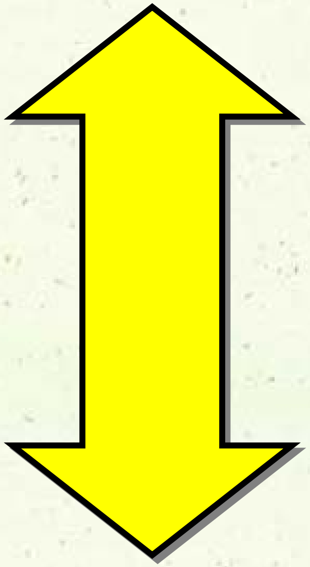
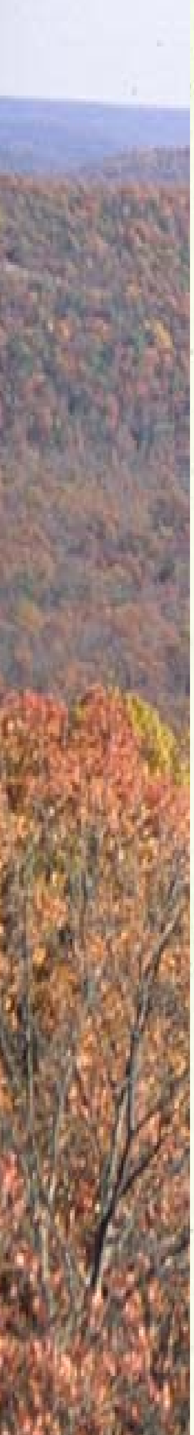
More detail in and detail out
Greater data cost/ha initialization



More effort for first output
Greater total project cost



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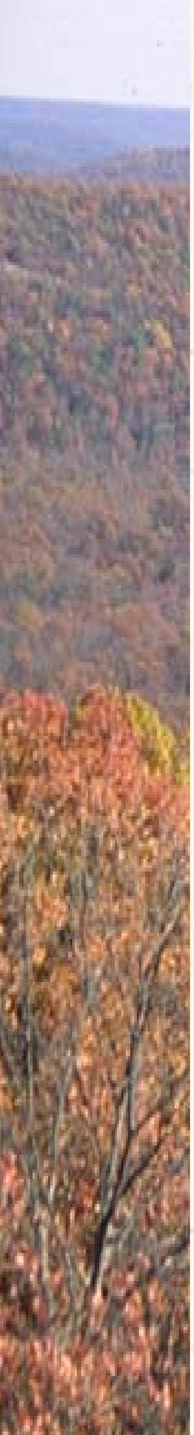
Available Options

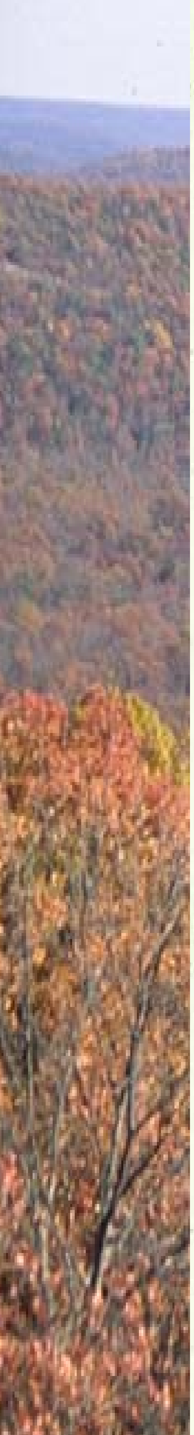
1. **Inexpensive**
2. **Fast**
3. **Useful**

You Can Pick Two



Modeling Tools By Scale

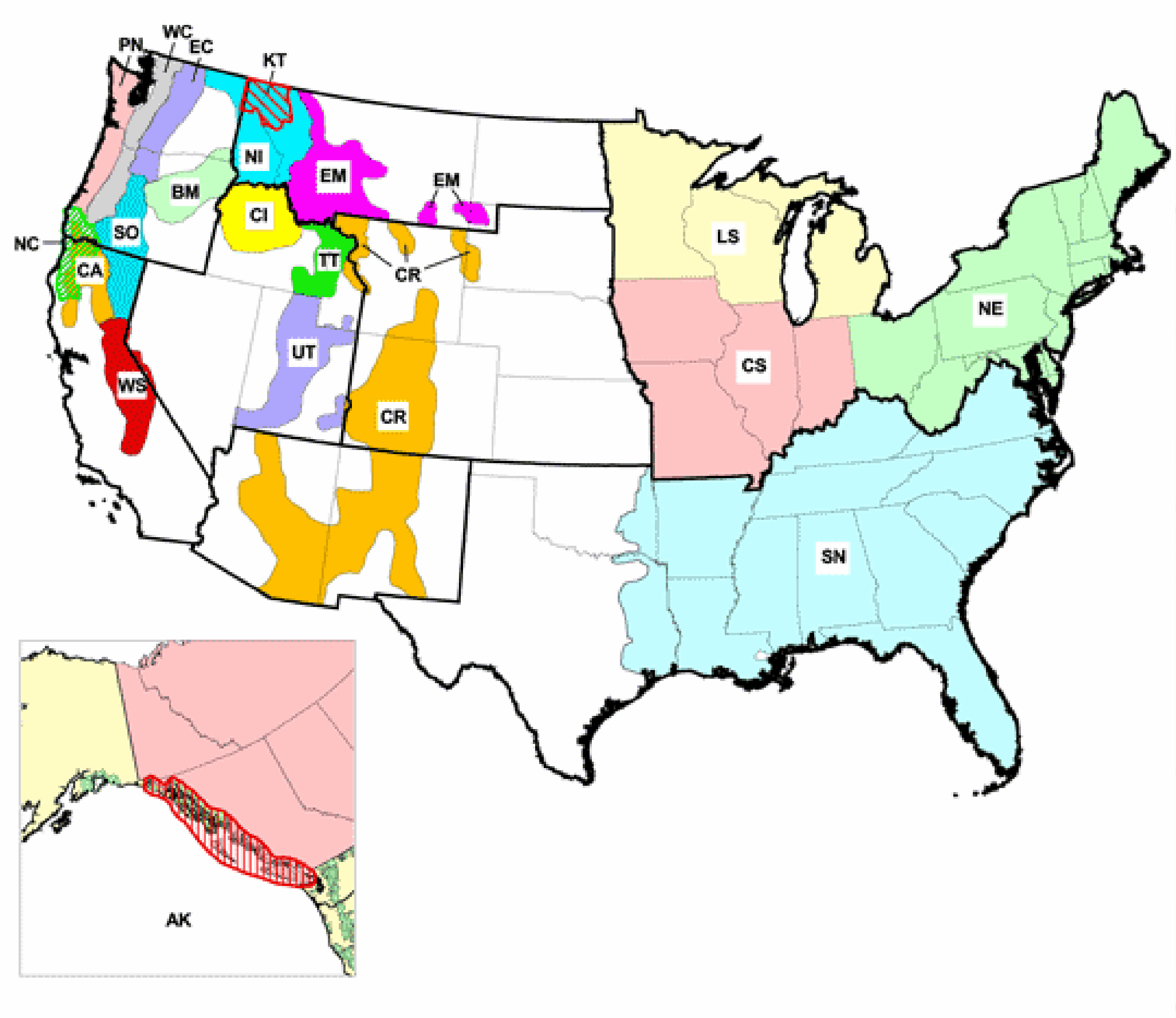
- Stand FVS
- Compartment LMS
- Landscape LMS, TELSA, HARVEST, LANDIS
- Ecoregions TELSA, HARVEST, LANDIS



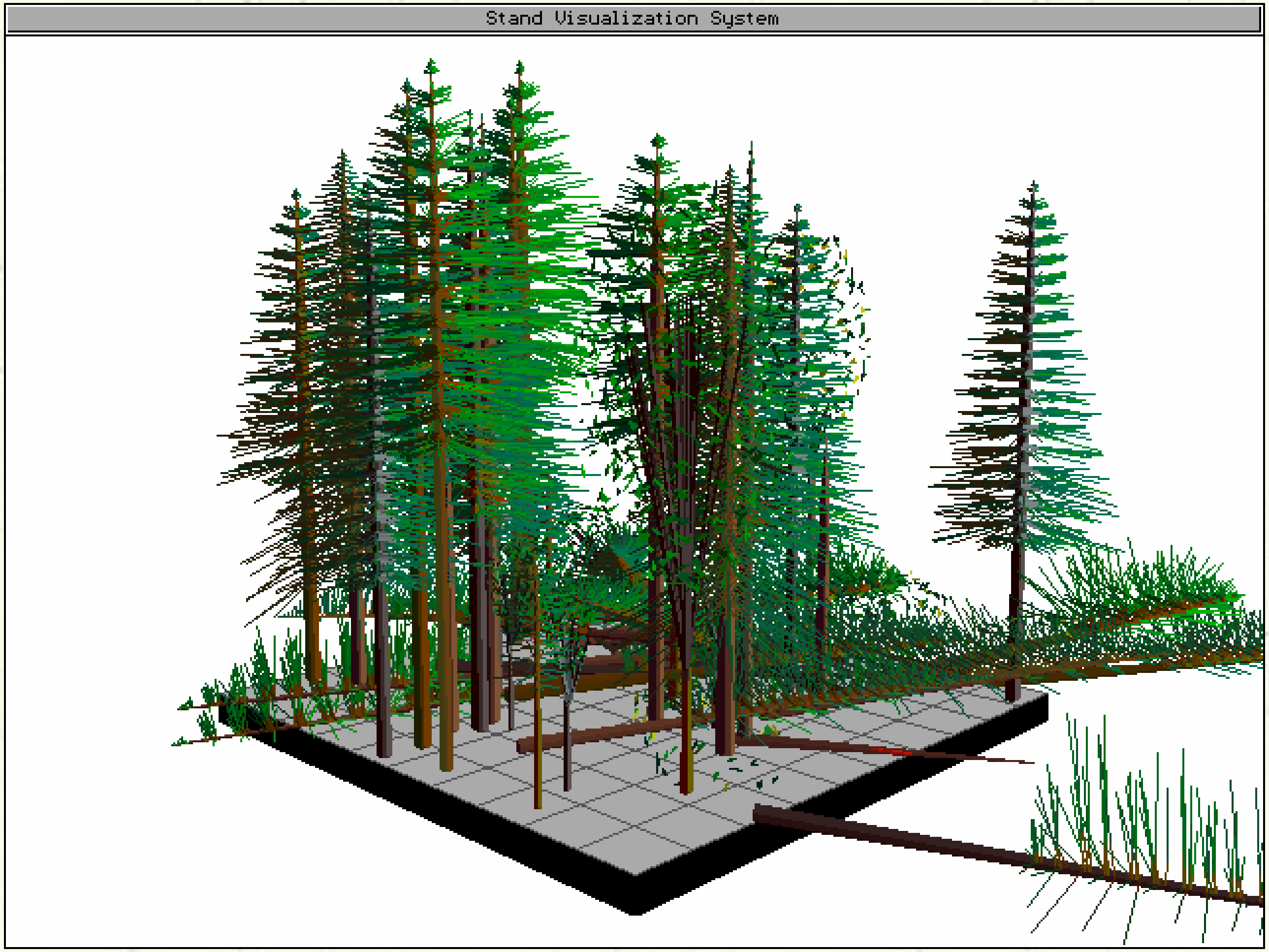
Forest Vegetation Simulator, FVS

- Based on inventory plots with sampled “tree lists”
  - For each sampled tree
    - Species
    - Dbh
    - Per acre expansion (sampling) factor
    - Height (optional)
    - Crown (optional)
- Predicts tree growth mortality, harvest, disturbance
- Summarize trees to get plot/ stand change over time
- Easy to run with a population of inventory plots
- Can link to FIA plots
- Limited options for spatial interaction among plots
- Wide geographic area of applicability

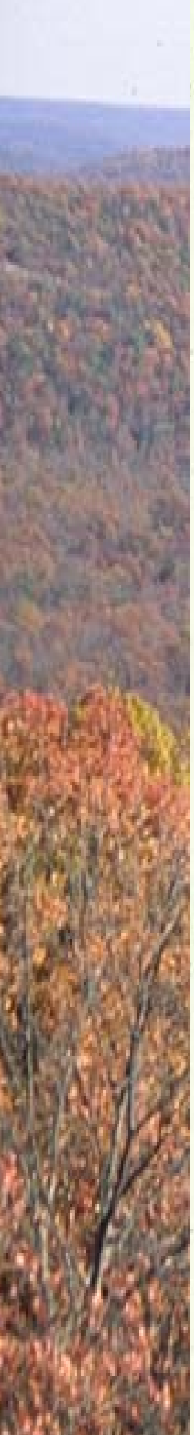
Forest Vegetation Simulator Variants

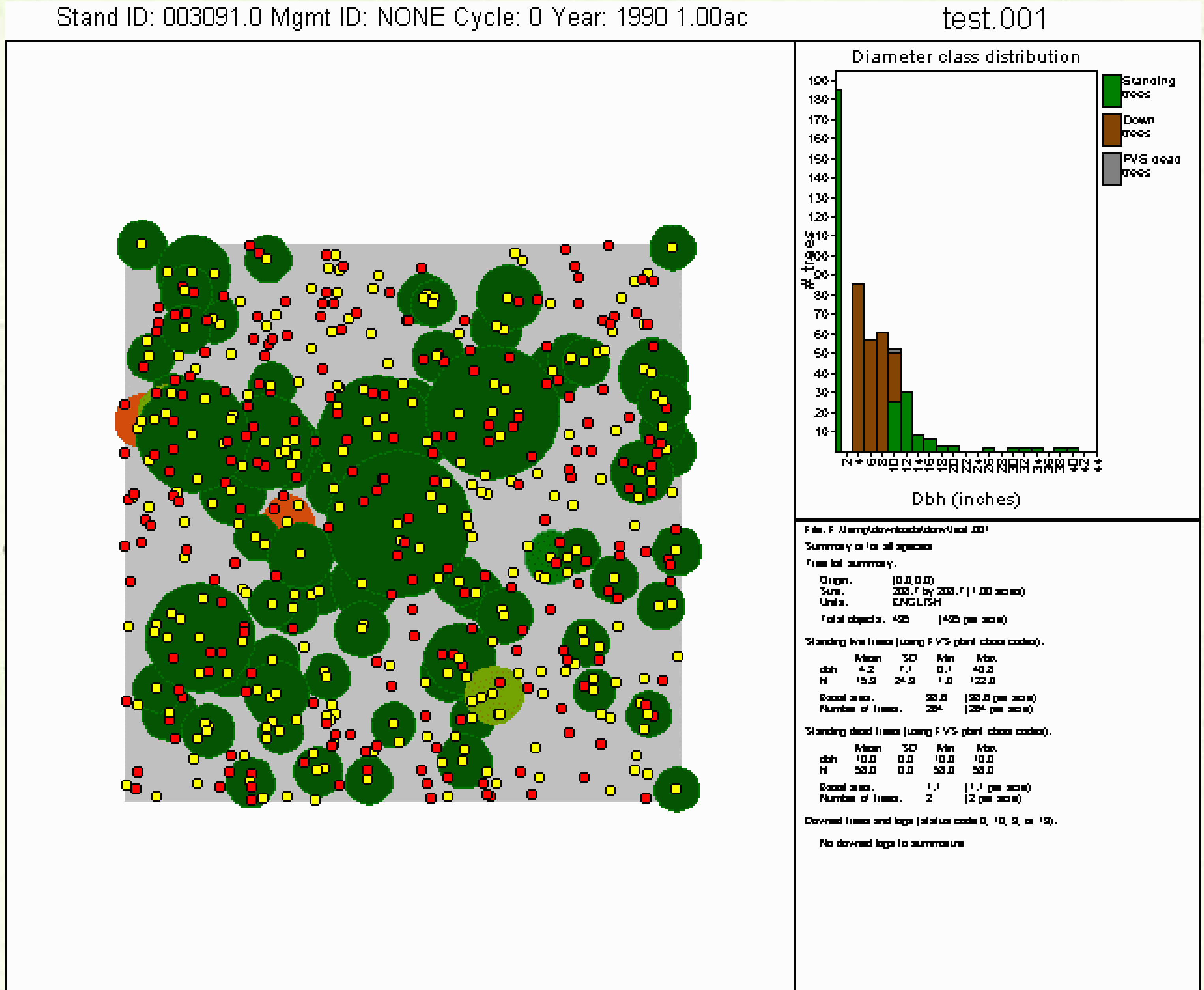


FVS links to Stand Visualization System

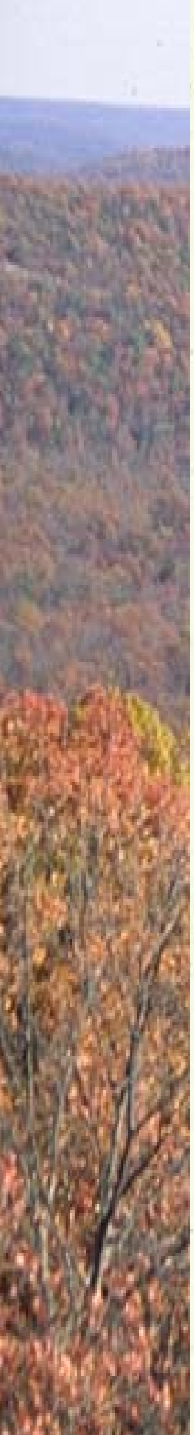


http://forsys.cfr.washington.edu/svs.html





Stand ID: 003091.0 Mgmt ID: NONE Cycle: 0 Year: 1990 1.00ac
test.001
Diameter class distribution
Standing trees
Down trees
FVS dead trees
Dbh (inches)
Tree list summary.
Origin.
(0.0,0.0)
Units.
ENGLISH
Mean
SD
Min
Max
dbh
Basal area.
Number of trees.
No downed logs to summarize

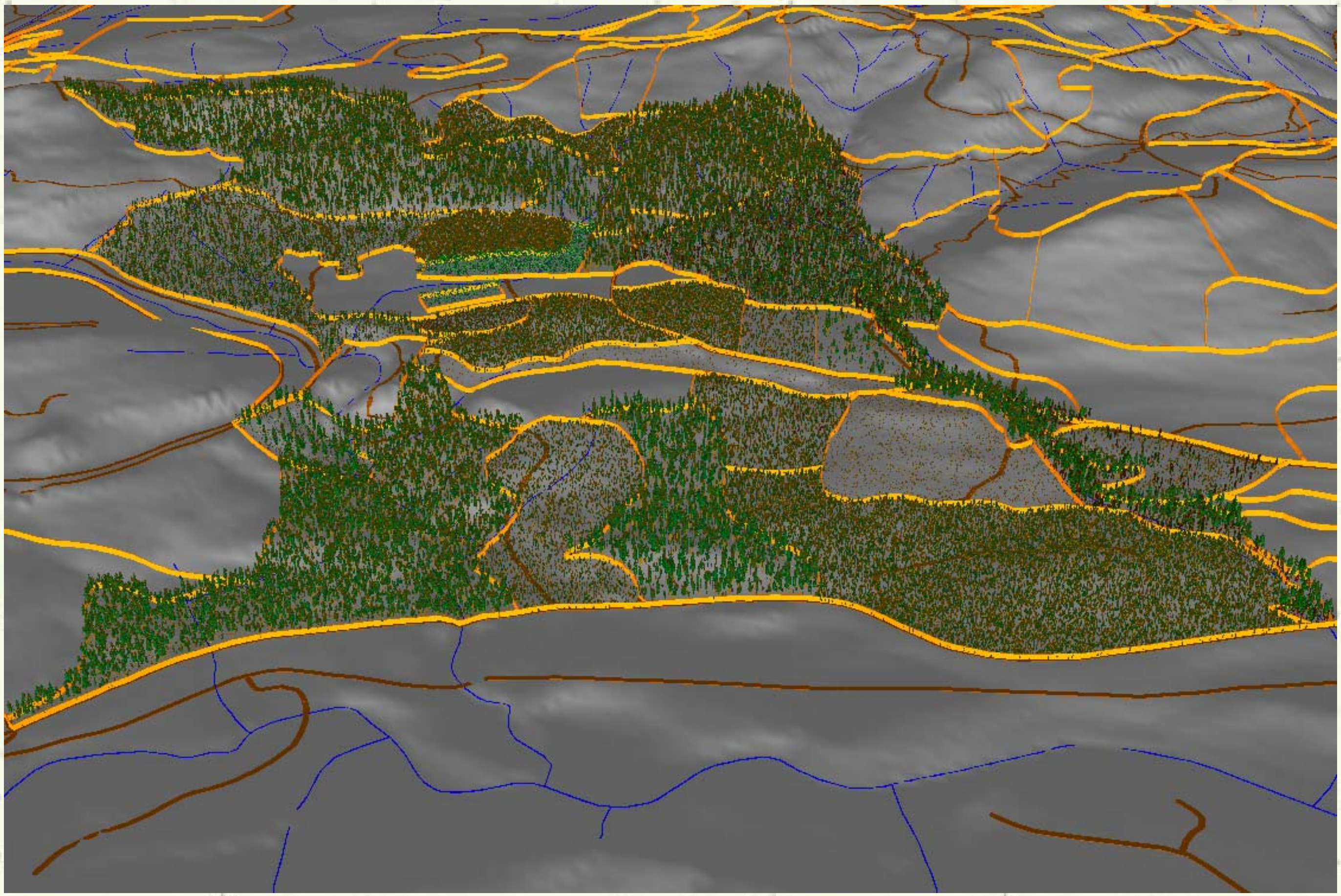


Forest Vegetation Simulator, FVS

- Tree/Stand based: 2 to 100ha (often too small for wildlife issues)
  - High resolution
  - Good stand dynamics for growth and survival
  - Excellent support
  - Limited regeneration modeling in the East
  - Data intensive
  - Consequently limited spatial scale
    - Initialization issues
    - Processing issues
  - SUPPOSE interface for multiple stands

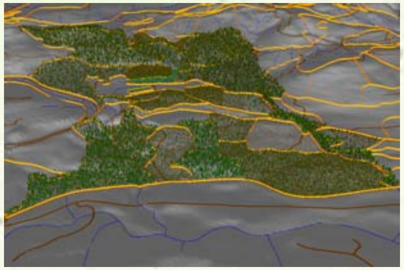
http://www.fs.fed.us/fmsc/fvs/
USDA Forest Service, Management Service Center, Ft. Collins

Landscape Management System (LMS)



http://lms.cfr.washington.edu

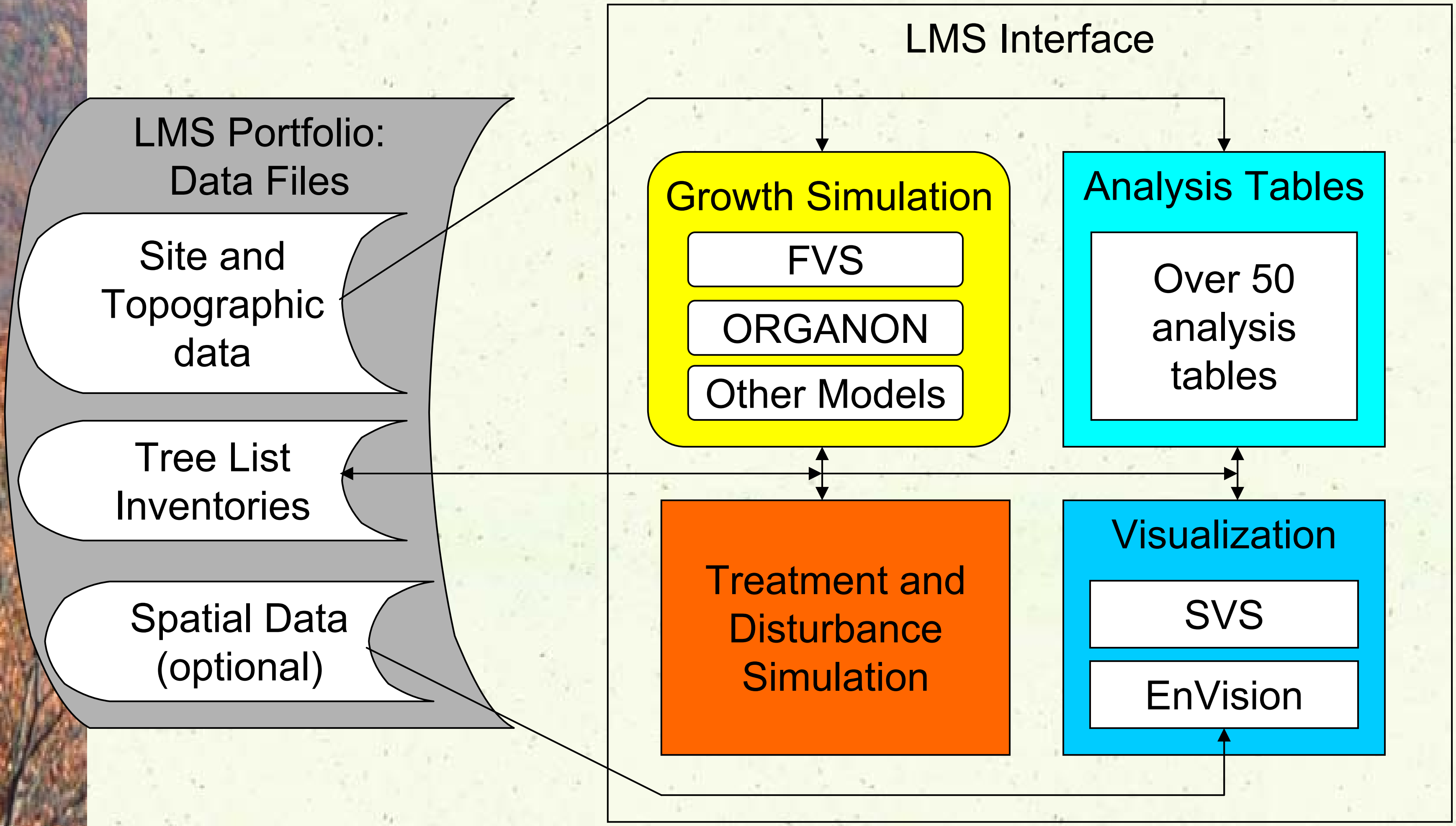
LMS



- Implements FVS for tree, stand and landscape dynamics
- Brings in terrain, GIS interface
- Powerful Display tools
- Excellent support
- A few stands to perhaps >10,000 stands

http://lms.cfr.washington.edu/

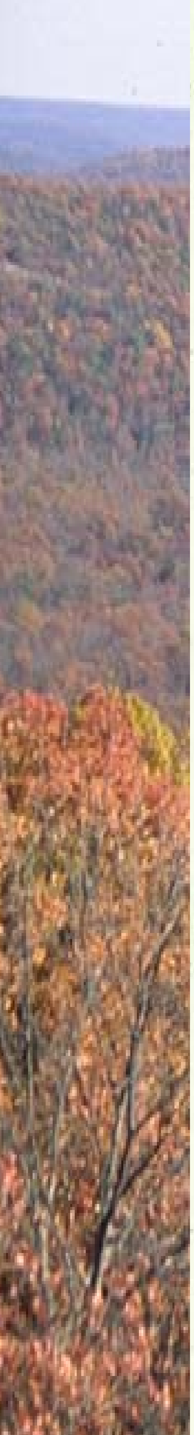
LMS Components



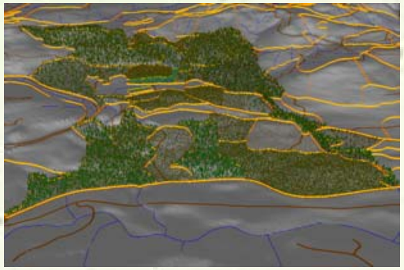
USDA Forest Service State & Private Forestry Cooperative Forestry

University of Washington College of Forest Resources

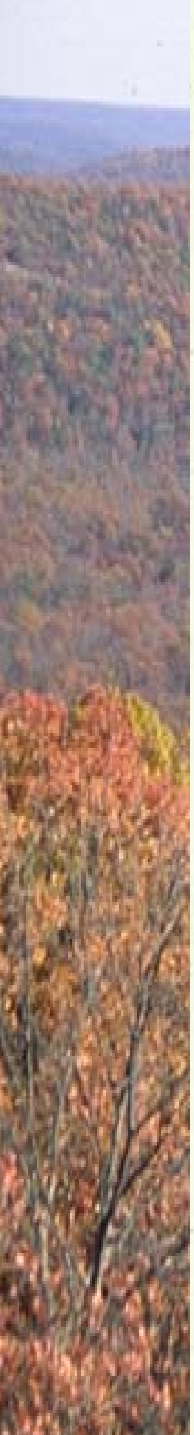
Washington State University



LMS



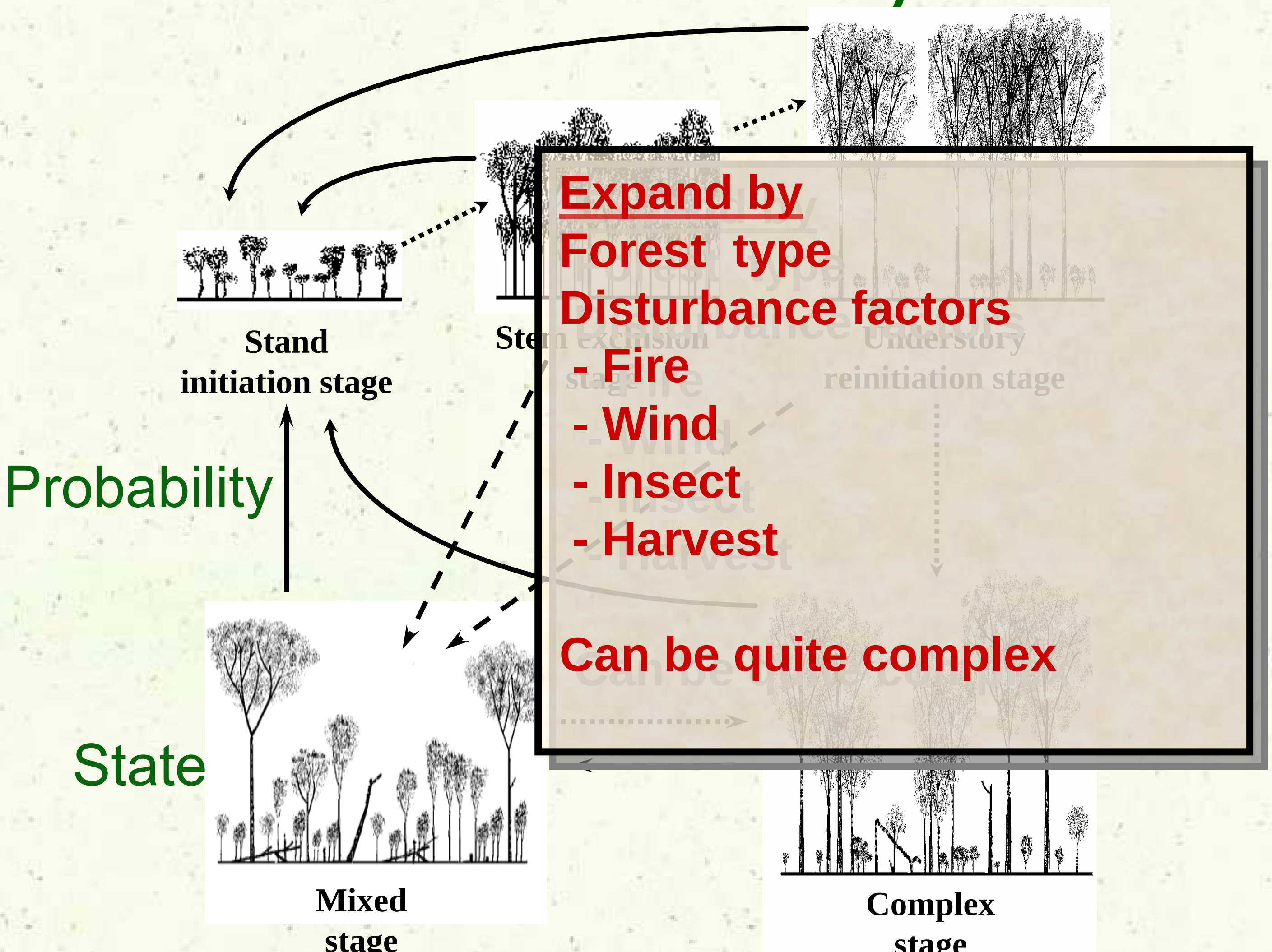
- Data intensive
  - Tree-level detail (same as FVS)
  - Spatial layers
- Hard to find a landscape with every stand sampled so you have to work around that for initial “tree lists”
- Excellent for one ownership with good inventory data
- Visually compelling …at a cost of time and effort



VDDT and TELSA

- Polygon based (e.g., stand based)
  - No tree-level data
- Pre-defined vegetation pathways and probabilities

Potential Vegetation Types and Pathways



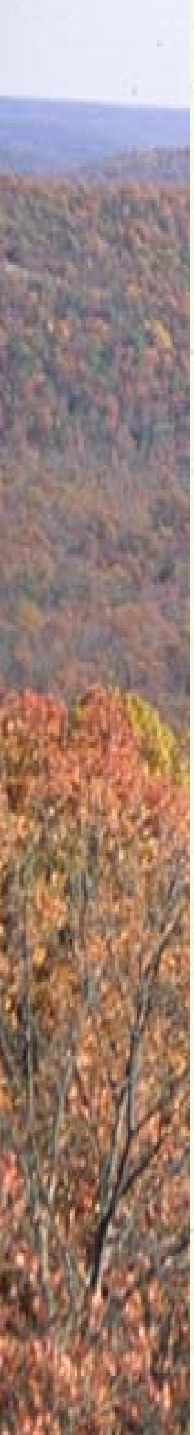
Expand by

Forest type

Disturbance factors

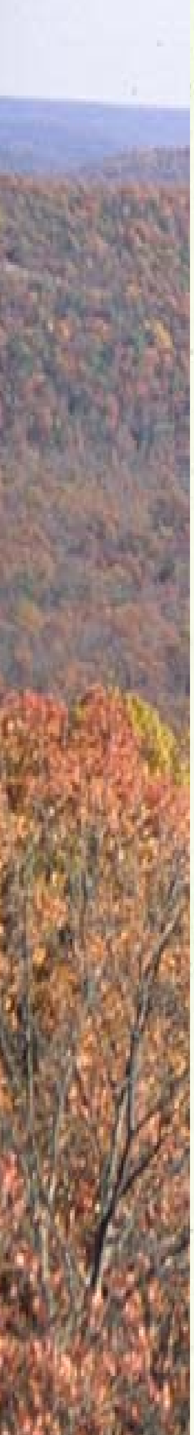
- **Fire**
- **Wind**
- **Insect**
- **Harvest**

Can be quite complex



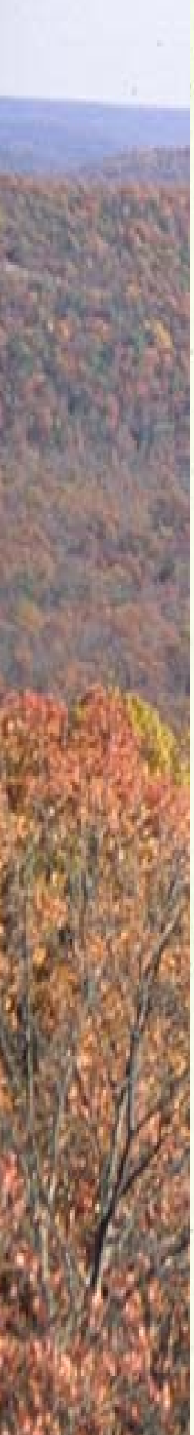
VDDT and TELSA

- Available from ESSA Technologies
  - http://www.essa.com/downloads/telsa/index.htm
- VDDT is free, TELSA is free only for research and education
- ArcView interface
- Mostly Western U.S. and Canadian applications
- Powerful display tools
- Up to about 250,000 ha
- Less detail, easier set up for large landscapes
- Visually less elegant than LMS
- Within-polygon detail, when needed, must be derived from vegetation types
  - Uneven-aged forest structure
  - Canopy gaps



Raster Based Models

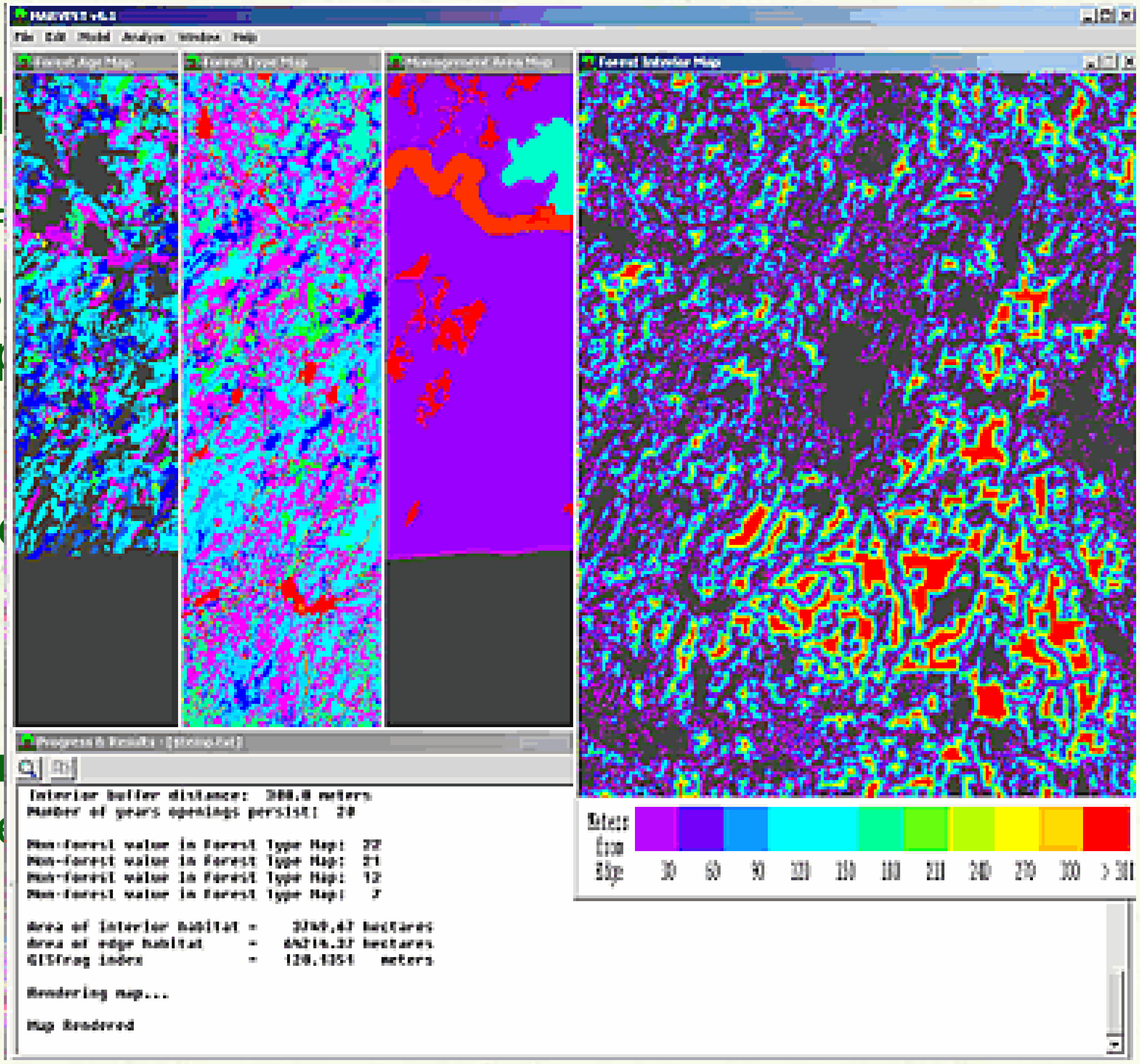
- HARVEST and LANDIS.
- Scaleable pixel size (10m to 1km).
- Works with or without stand boundaries.
- At finer resolutions can show within-stand variability (gaps, uneven-age/size structure, multiple species) resulting from harvest or other disturbance.
- Large scale, large investment, potentially high utility.

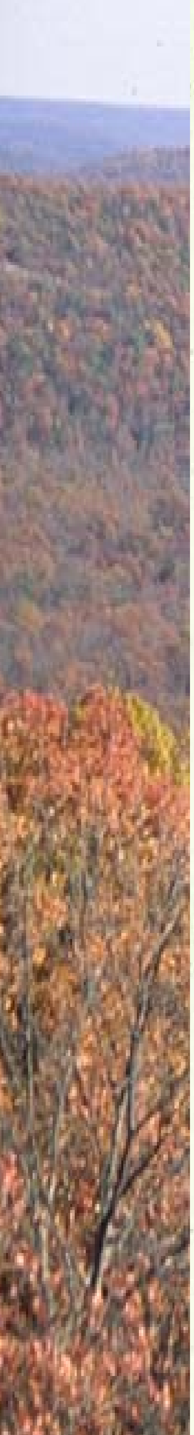


HARVEST Model

- Age-based harvest.
- Designed f
- Easy-to-us
- Can be app
- Good way placement
- Limited tree focus is on
- No natural

Eric Gustafson
http://ncrs.fs.fe

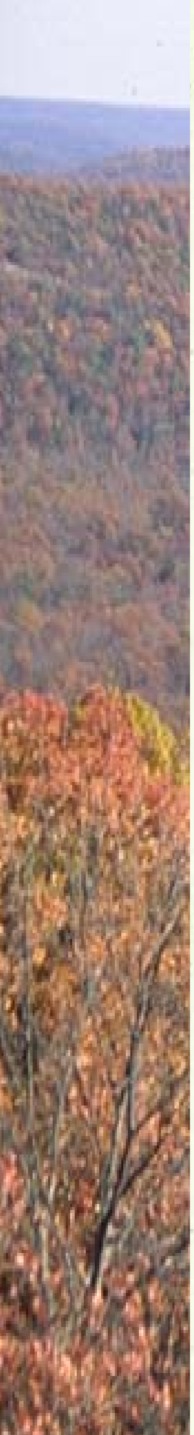




LANDIS

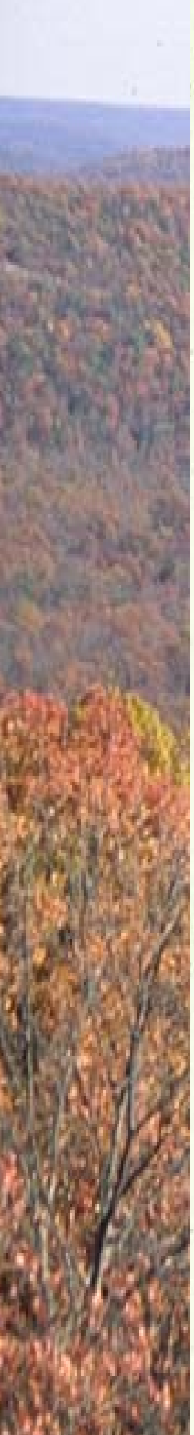
- Developed by David J. Mladenoff and colleagues, Un WI-Madison
  http://landis.forest.wisc.edu/
  Hong He, University of Missouri at Columbia
  http://www.snr.missouri.edu/LANDIS/landis
  Linked to RAMAS
  http://www.ramas.com/landsc.htm

- Large number of colleagues working on applications and extensions
  - Forest management in the Northern Lake States
  - Effects of climate warming in N Wisconsin
  - LANDIS in the Ozarks of Missouri
  - LANDIS in southern Indiana
  - LANDIS in the California Chaparral
  - LANDIS in the Southeastern pine ecosystems
  - LANDIS in Finland
  - LANDIS in British Columbia
  - Fire simulation
  - Pest models
  - Software enhancements

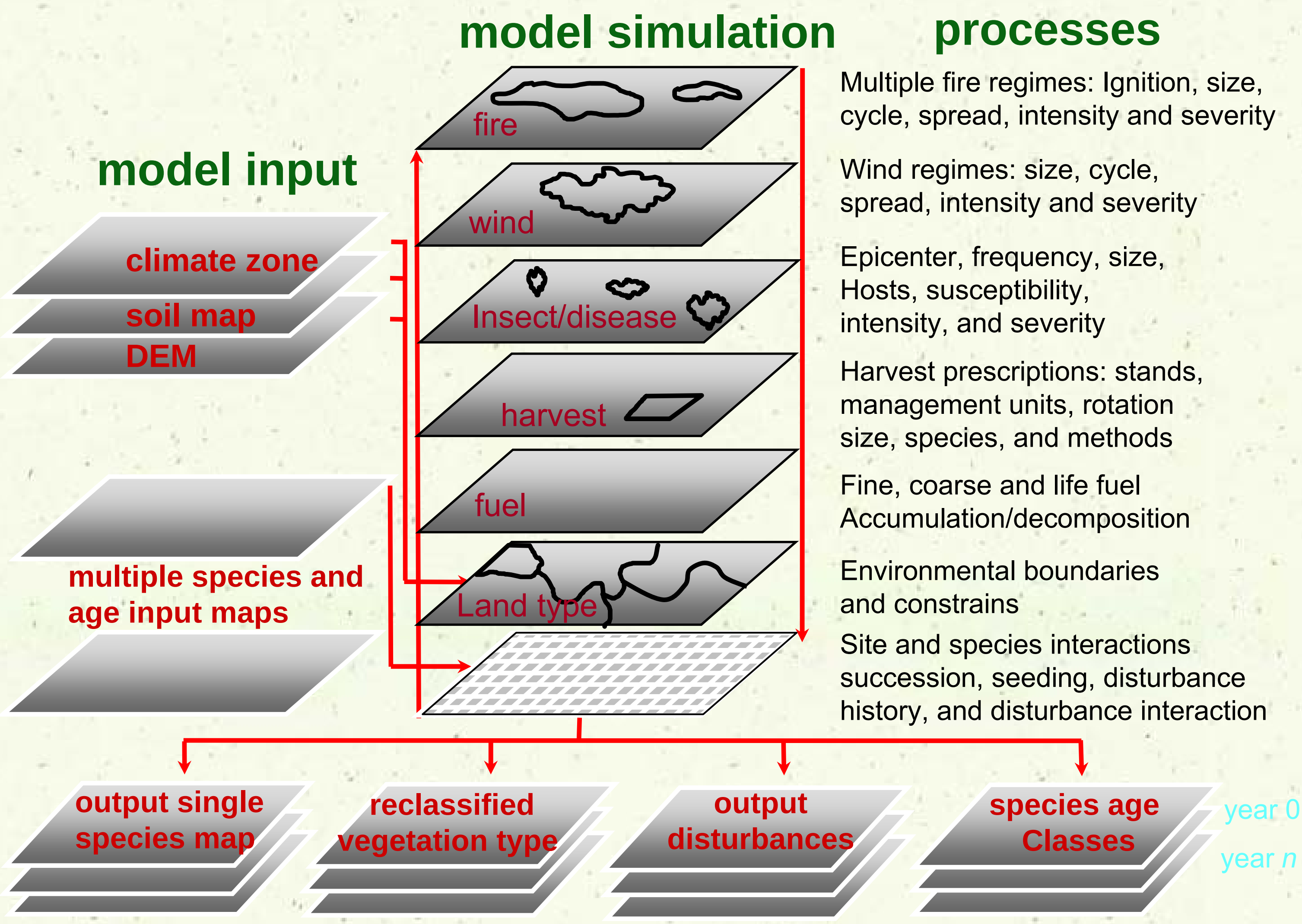


LANDIS model

- Generic framework for simulating landscape change in response to disturbance
- Tool for evaluating outcomes of alternative (disturbance) scenarios
- Handles all the basic bookkeeping and mapping
- Scaleable pixel size
  - (10m to 1,000m; 0.01ha to 1km)
- Tracks presence/absence of tree species on each pixel by age and location
- Must be calibrated for local forest conditions (not trivial)
- Simulates stochastic fire events
- Simulates stochastic wind events
- Harvest simulator



LANDIS Operational Design



LANDIS Representation of a Site (pixel)

Species 10 year age classes 1 = present, 0 = absent

Age 0------------------------------------→ Age 240

Growth

Fire

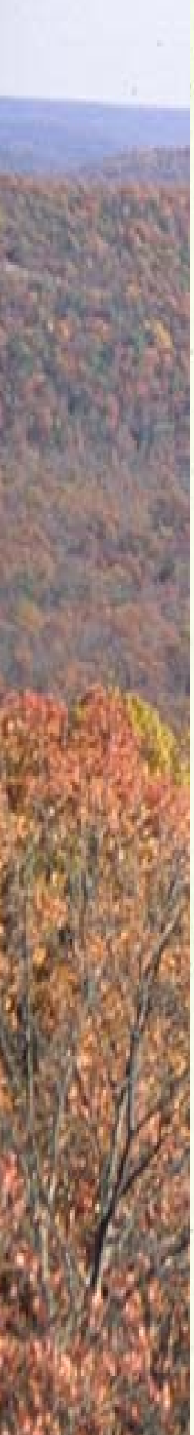
Maple	**1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
Shortleaf	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
Black oak	**0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0**
White oak	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

Mortality

Wind

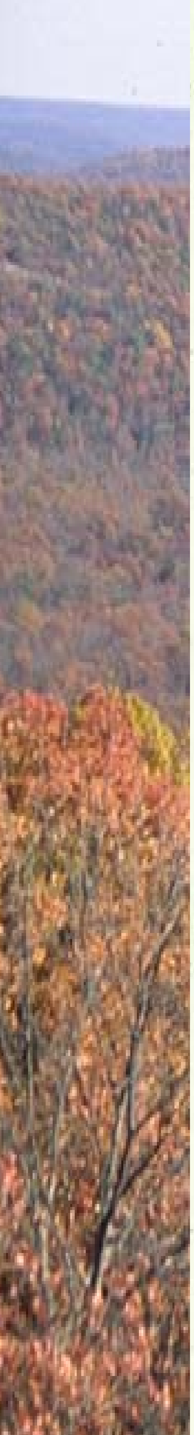
Succession

Harvest



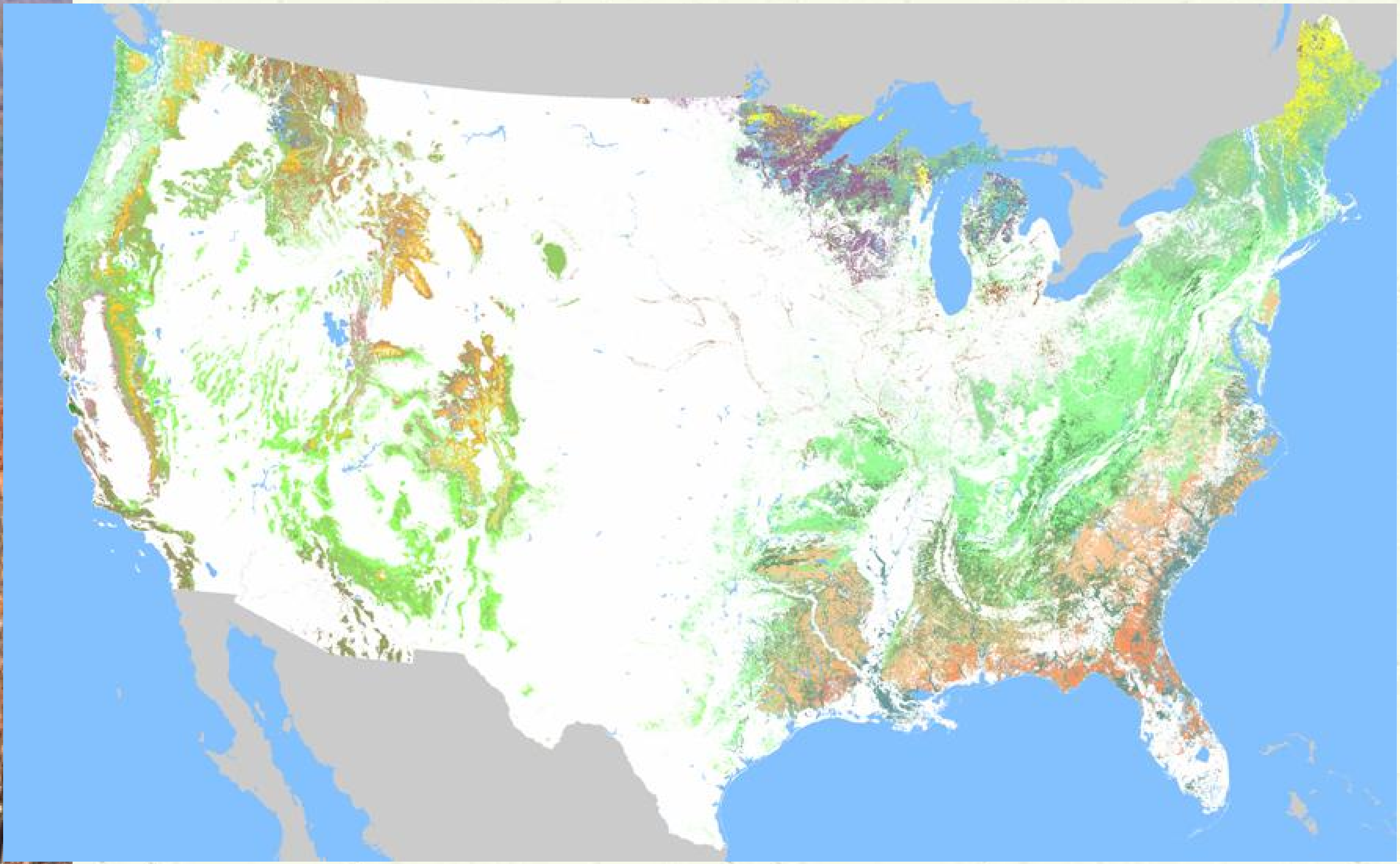
Calibration Process for LANDIS

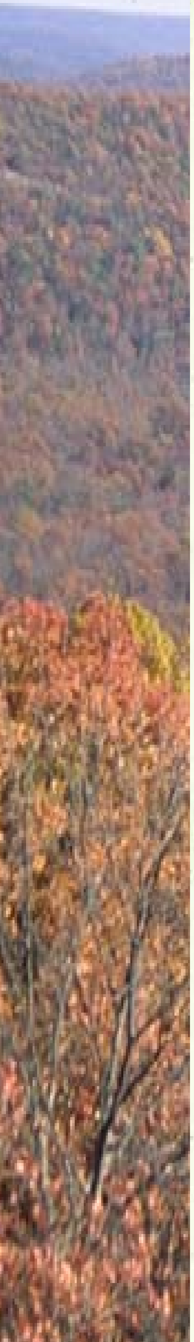
- **Identify Land Units (ecological land types)**
- **Calibrate species reproduction and survival dynamics based on life history characteristics**
  - **Longevity, shade tolerance, fire tolerance, dominance**
  - **Sprouting, age to sexual maturity, seed dispersal**
  - **Reproduction probability**
- **Calibrate wind and fire disturbance**
  - **Frequency (return interval), size, severity**



Required Input Maps (raster)

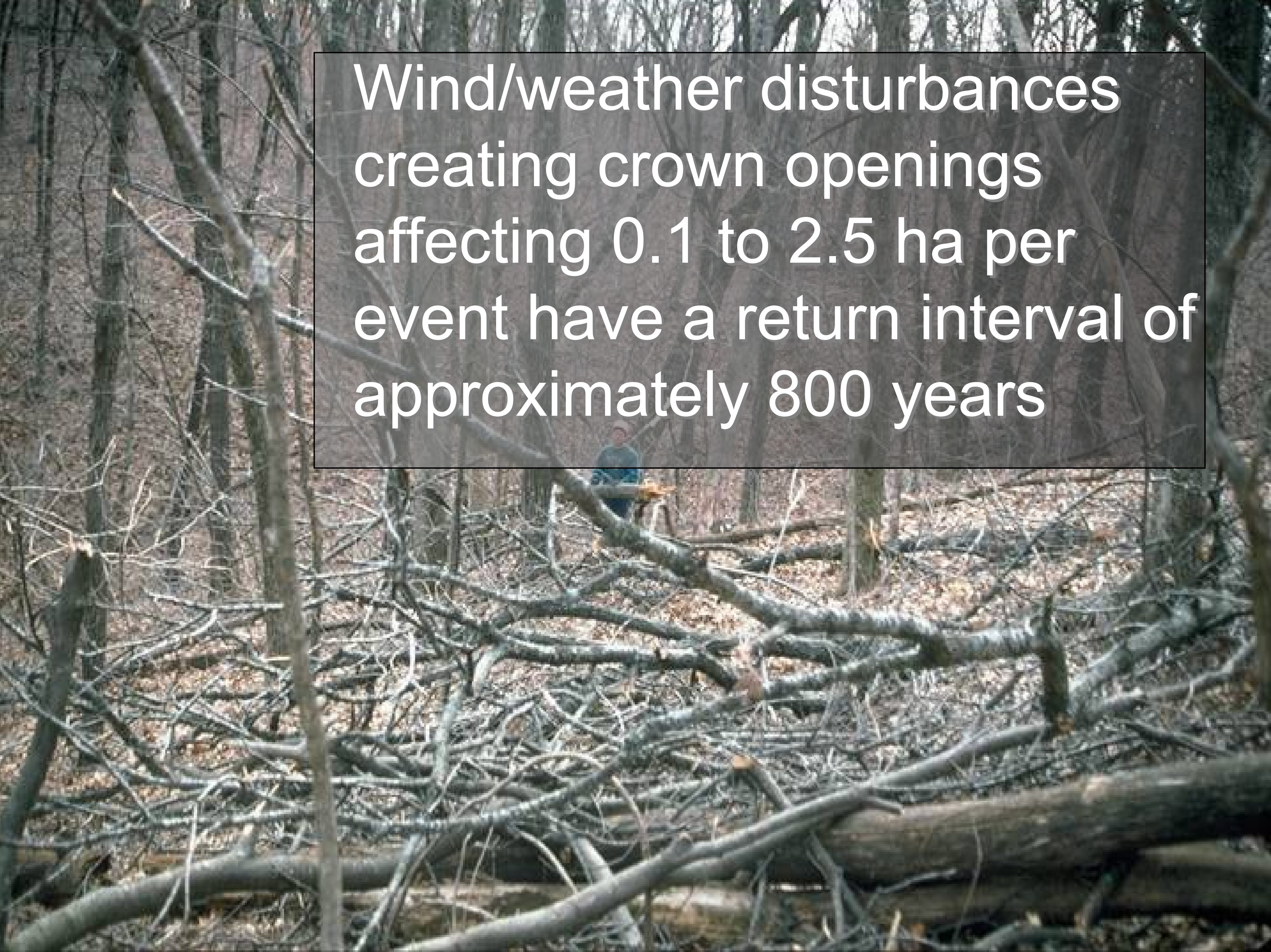
- **Land units (ecological classification system)**
- **Initial vegetation cover and age class**
- **Additional maps required to simulate harvest**
  - **Management area (any group of stands)**
  - **Stand boundaries**

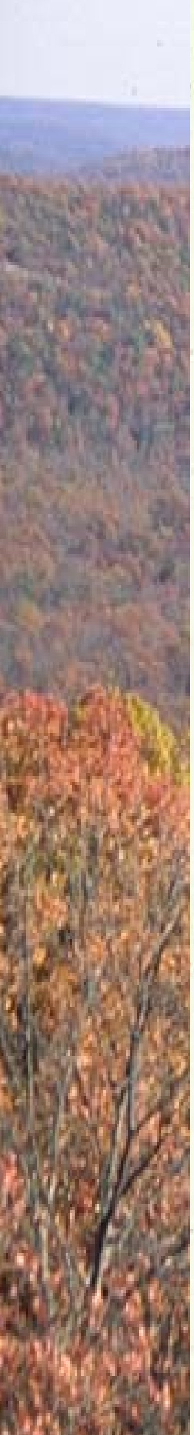




Fires once were common
-- Every 4-7 years in 1800’s
With active suppression the
mean fire return interval
is now about 300 years.
-- Crown fires are rare


Wind/weather disturbances creating crown openings affecting 0.1 to 2.5 ha per event have a return interval of approximately 800 years



Selected Harvest Options

Harvest per decade 5%	Harvest per decade 10%	Harvest treatment
✓	✓	Even-aged (clearcut)
✓	✓	Uneven-aged (group selection)
✓	✓	Mixed
		No harvest

Even-aged management by clearcut

Uneven-aged management by group selection


Age 0


Age 5


Age 10


Age 15

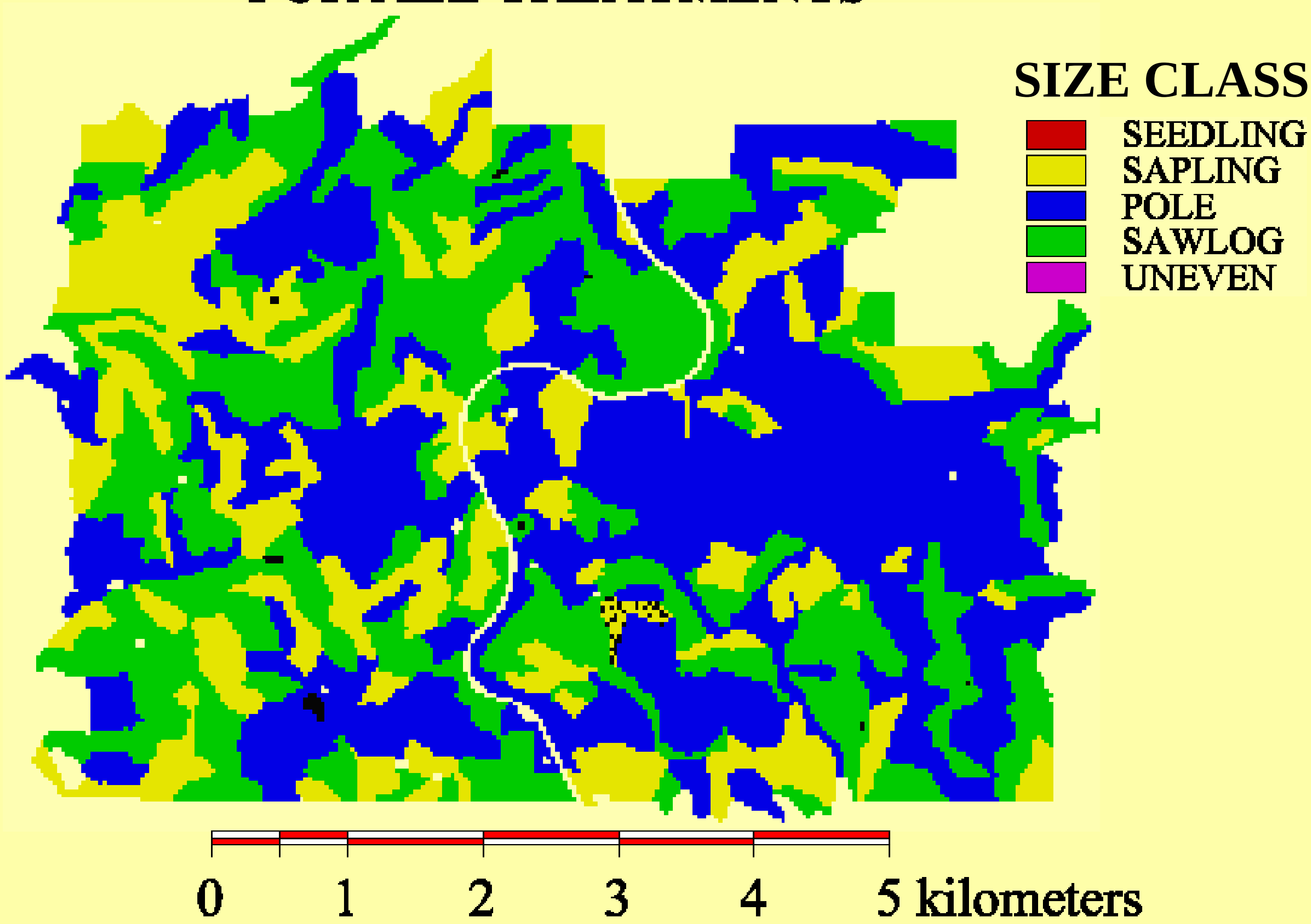

Age 28


Age 50

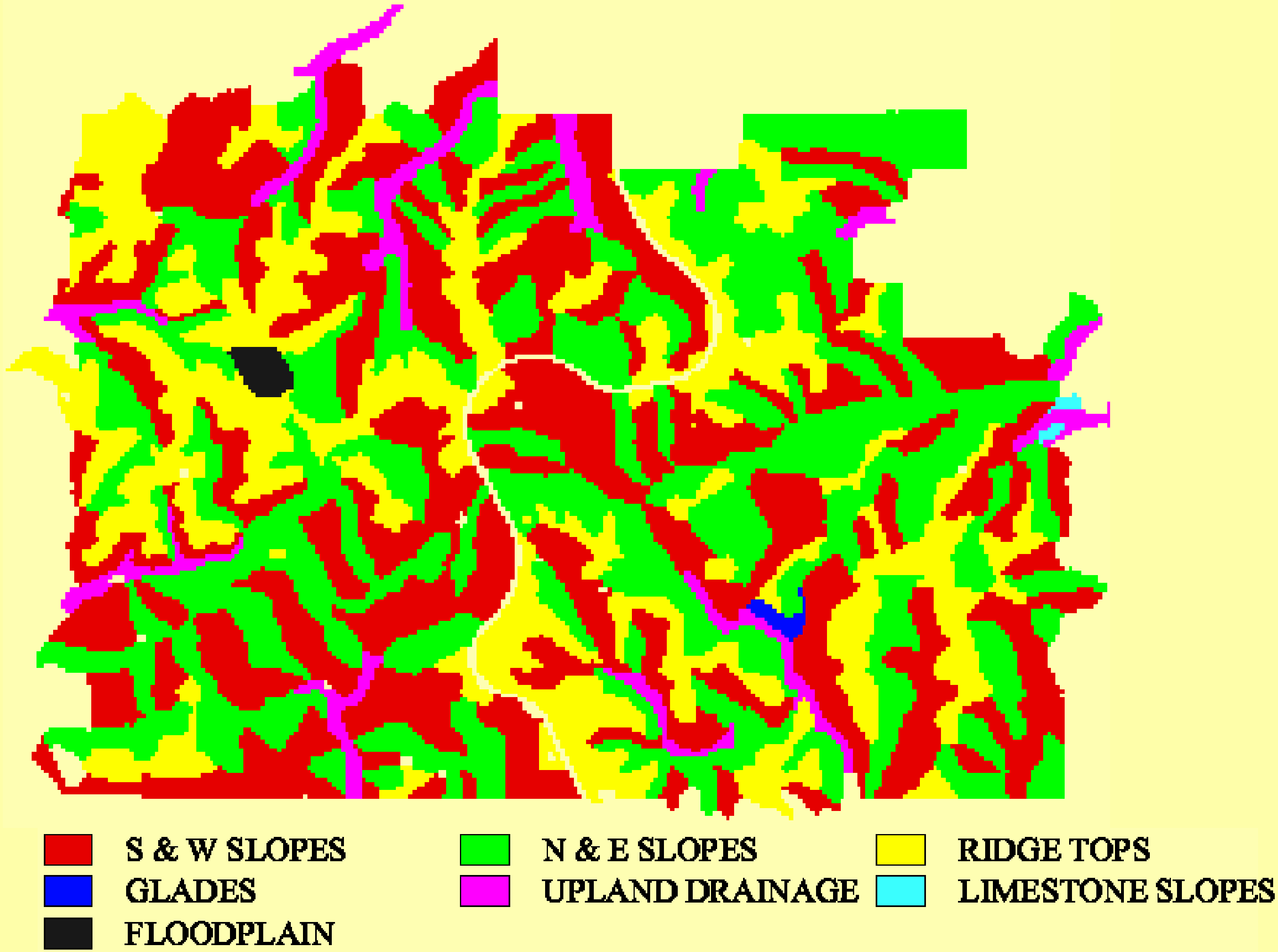

Age 90


Age 120+

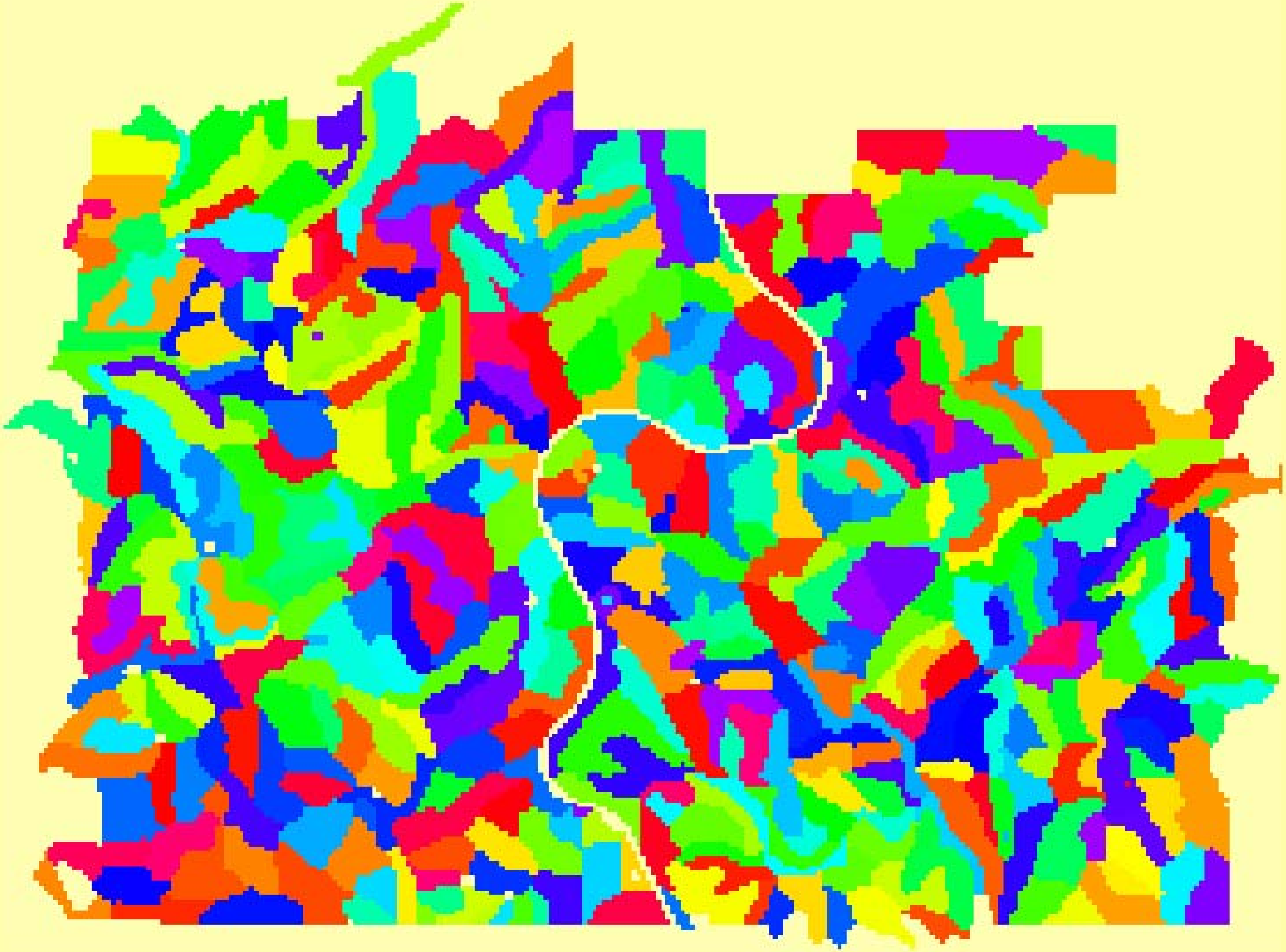
INITIAL SIZE CLASSES FOR ALL TREATMENTS



ECOLOGICAL LAND TYPE

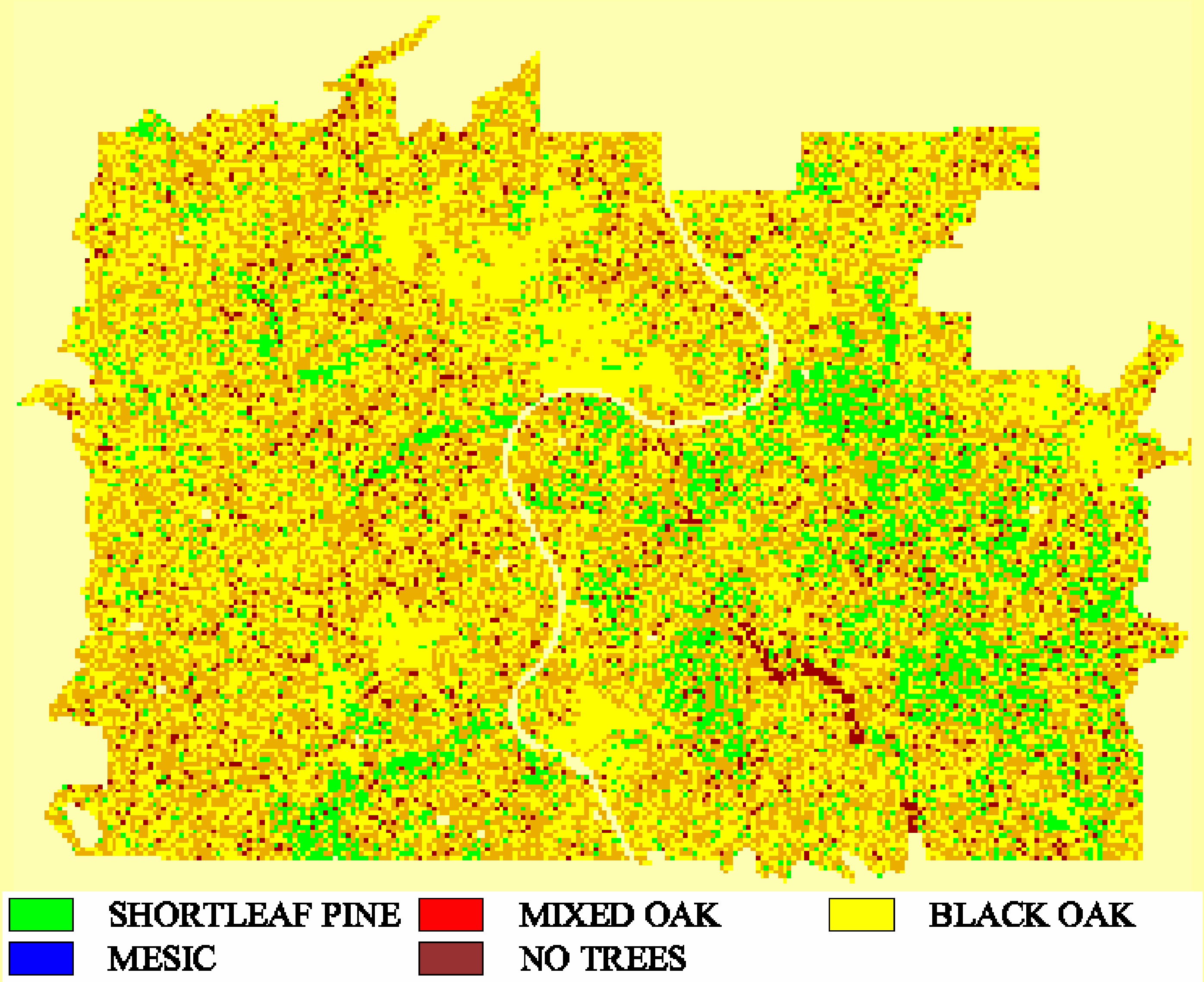


STAND MAP

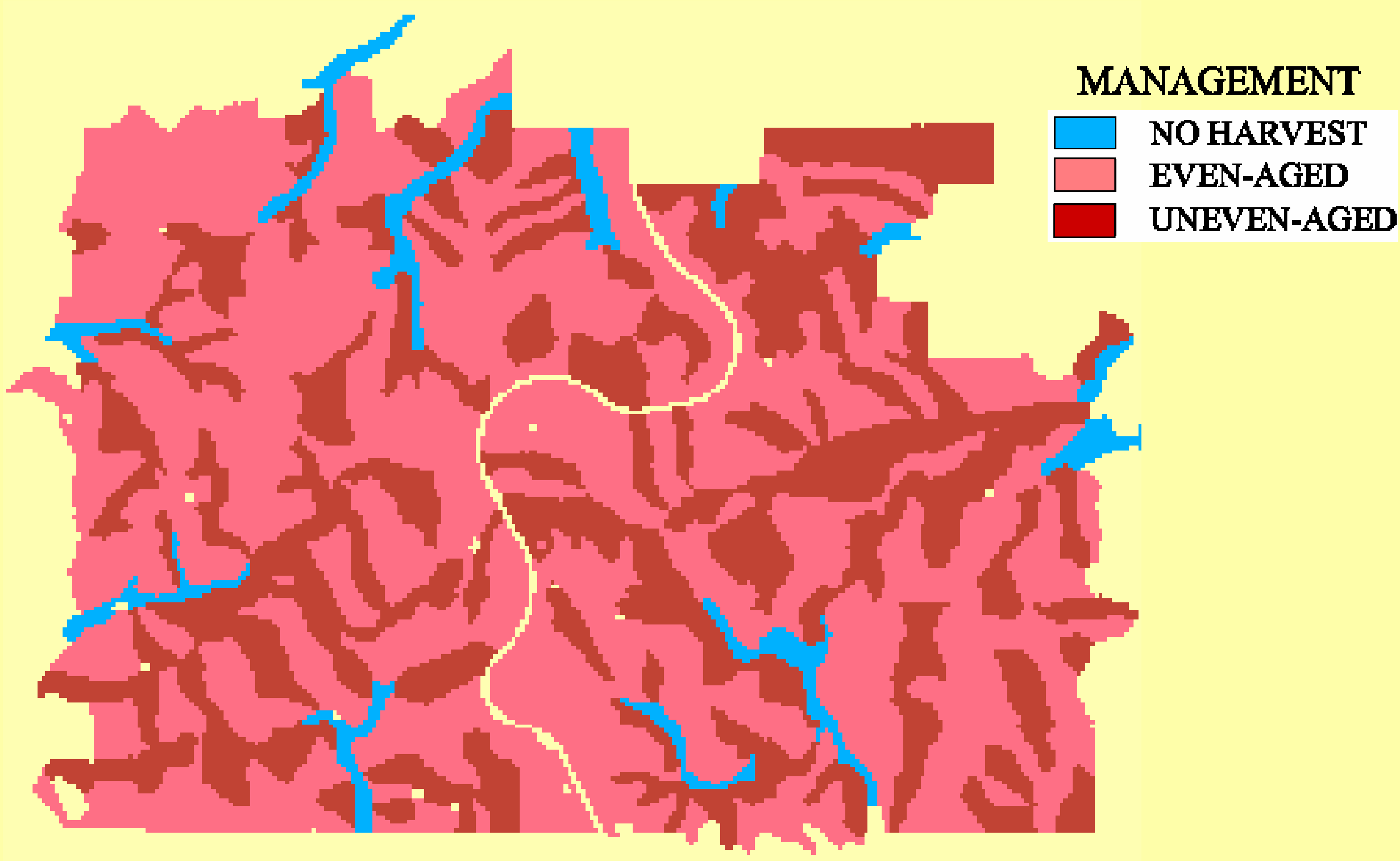


450 STANDS - MARK TWAIN NATIONAL FOREST

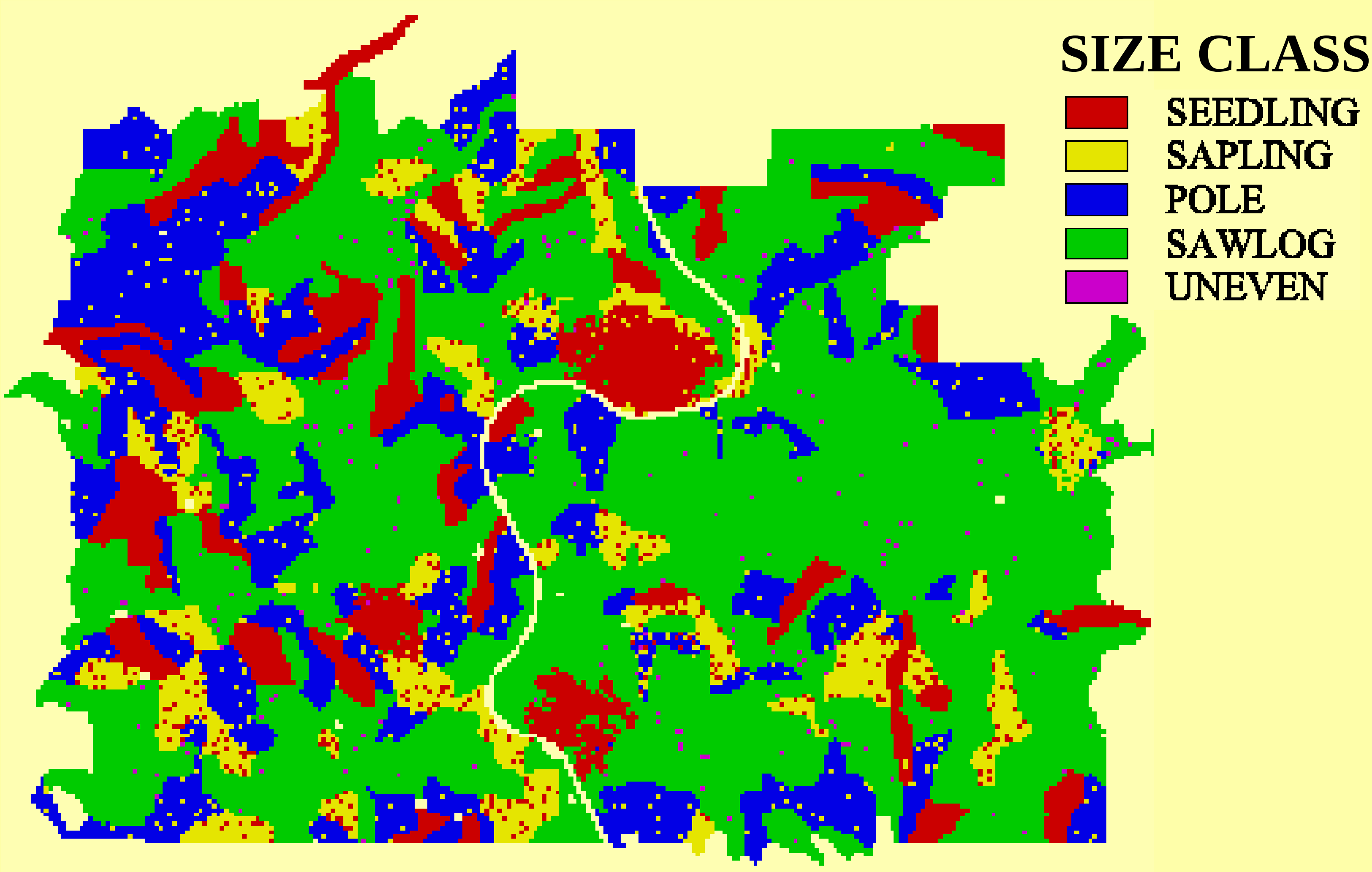
INITIAL FOREST TYPE



MIXED MANAGEMENT UNITS

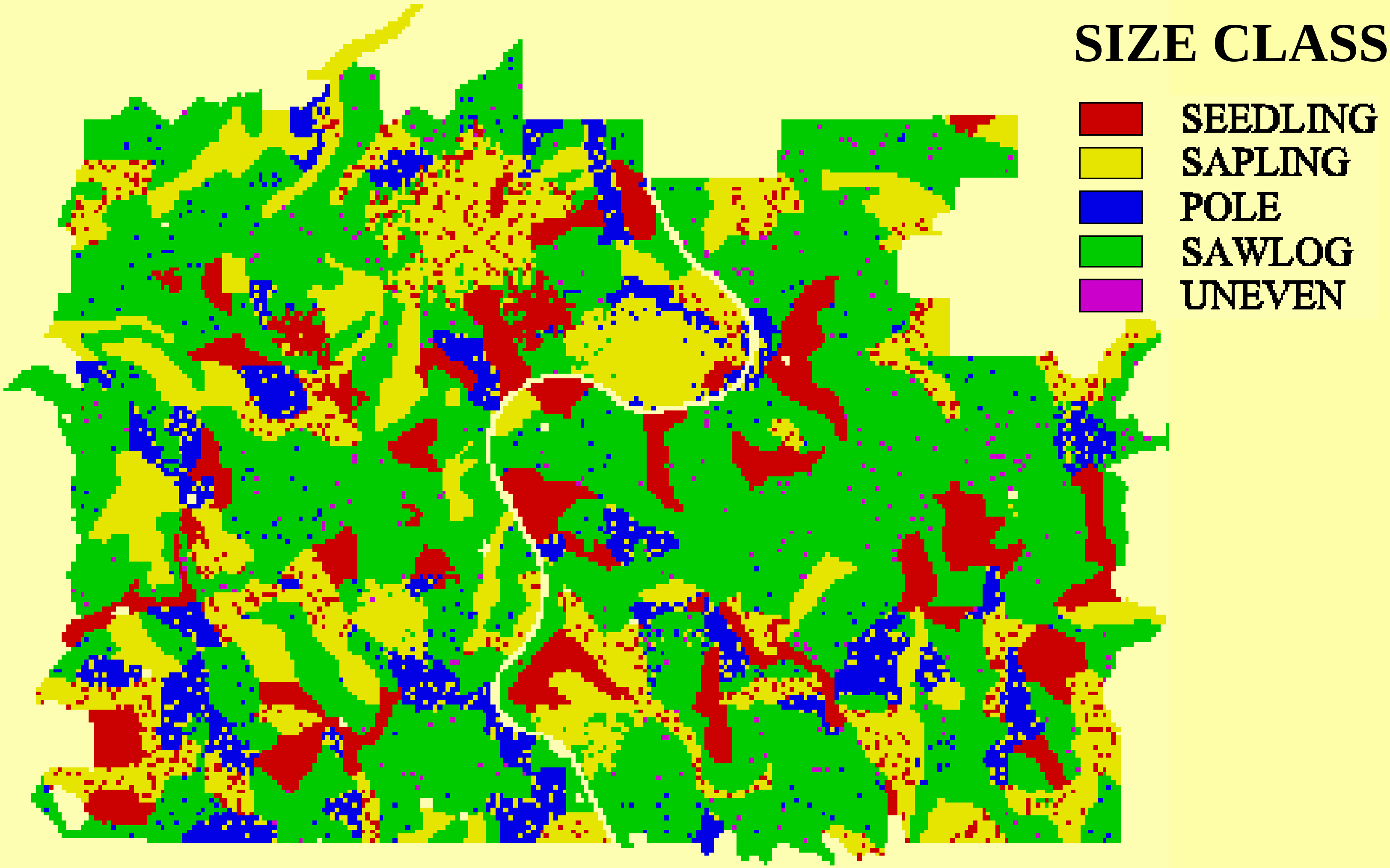


EVEN-AGED INTENSIVE MANAGEMENT



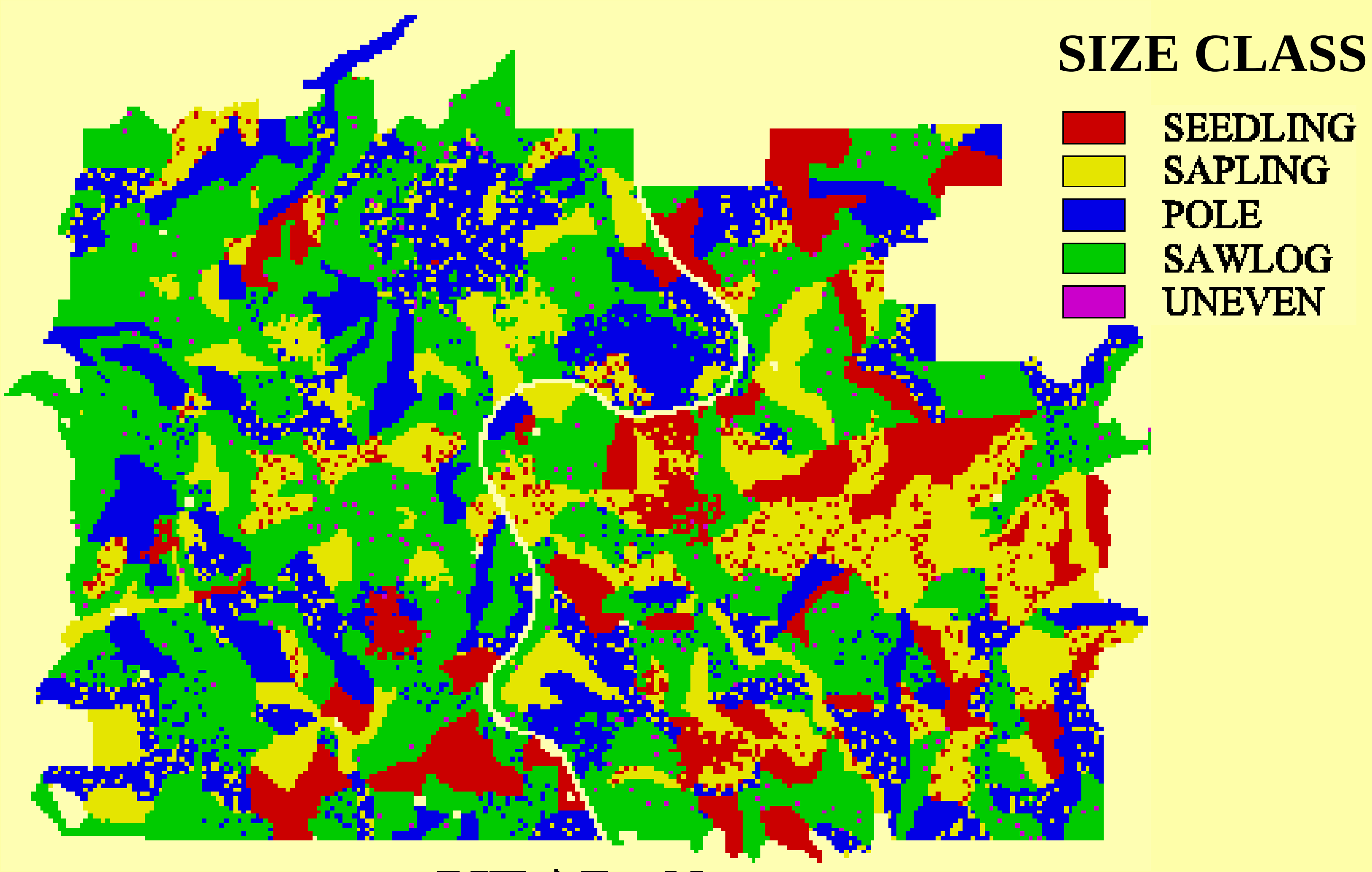
YEAR 20

EVEN-AGED INTENSIVE MANAGEMENT



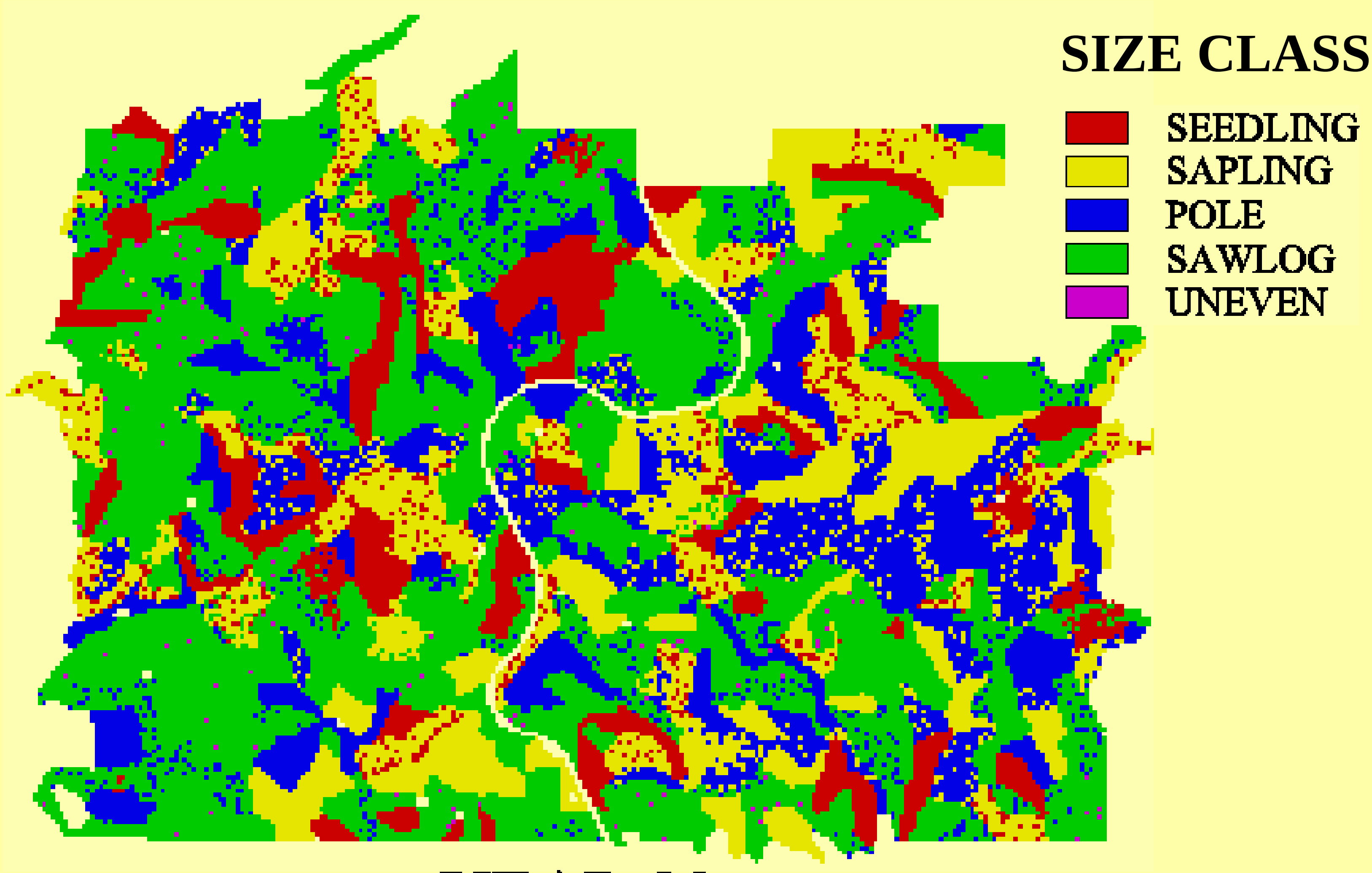
YEAR 40

EVEN-AGED INTENSIVE MANAGEMENT



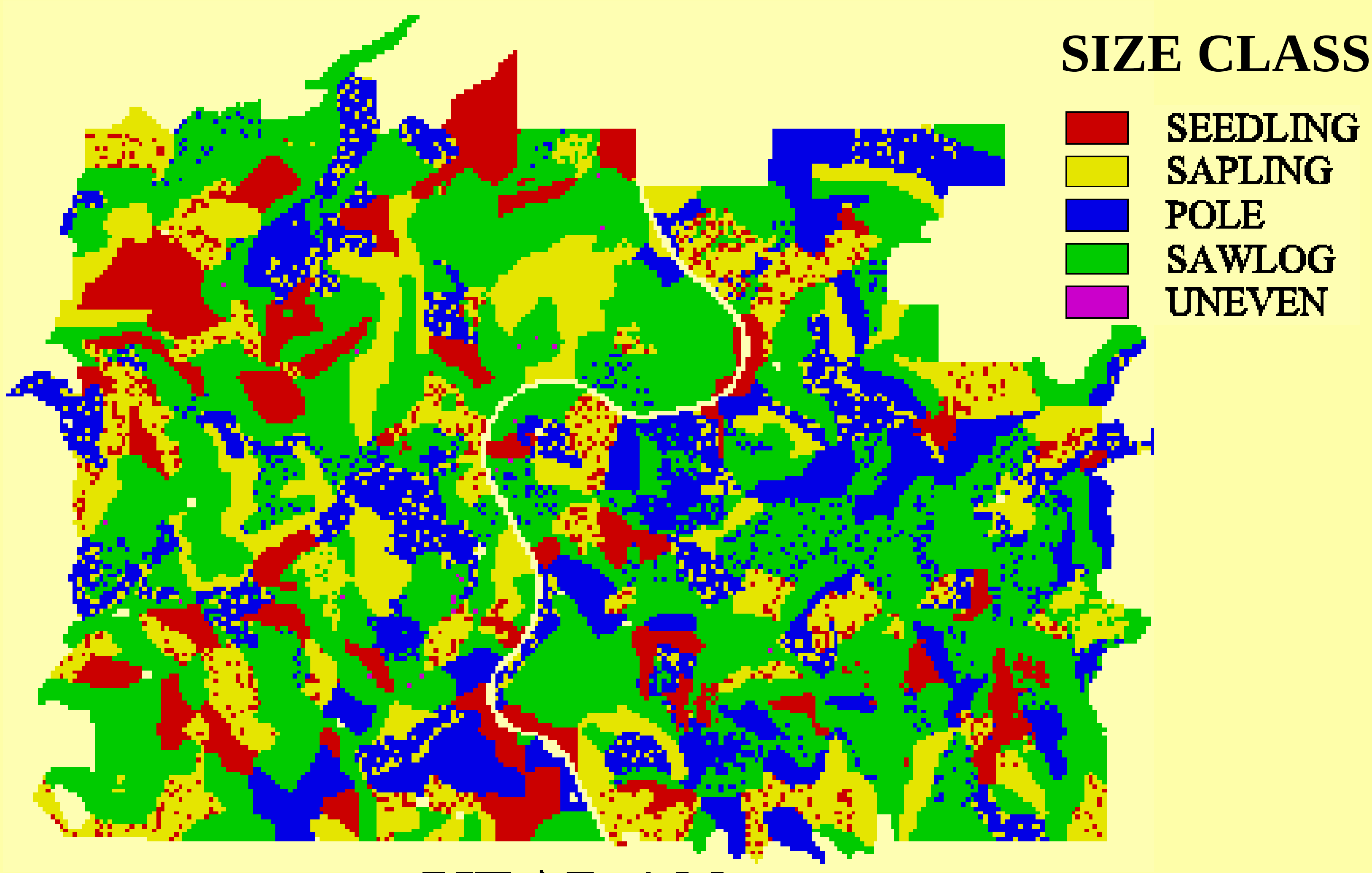
YEAR 60

EVEN-AGED INTENSIVE MANAGEMENT



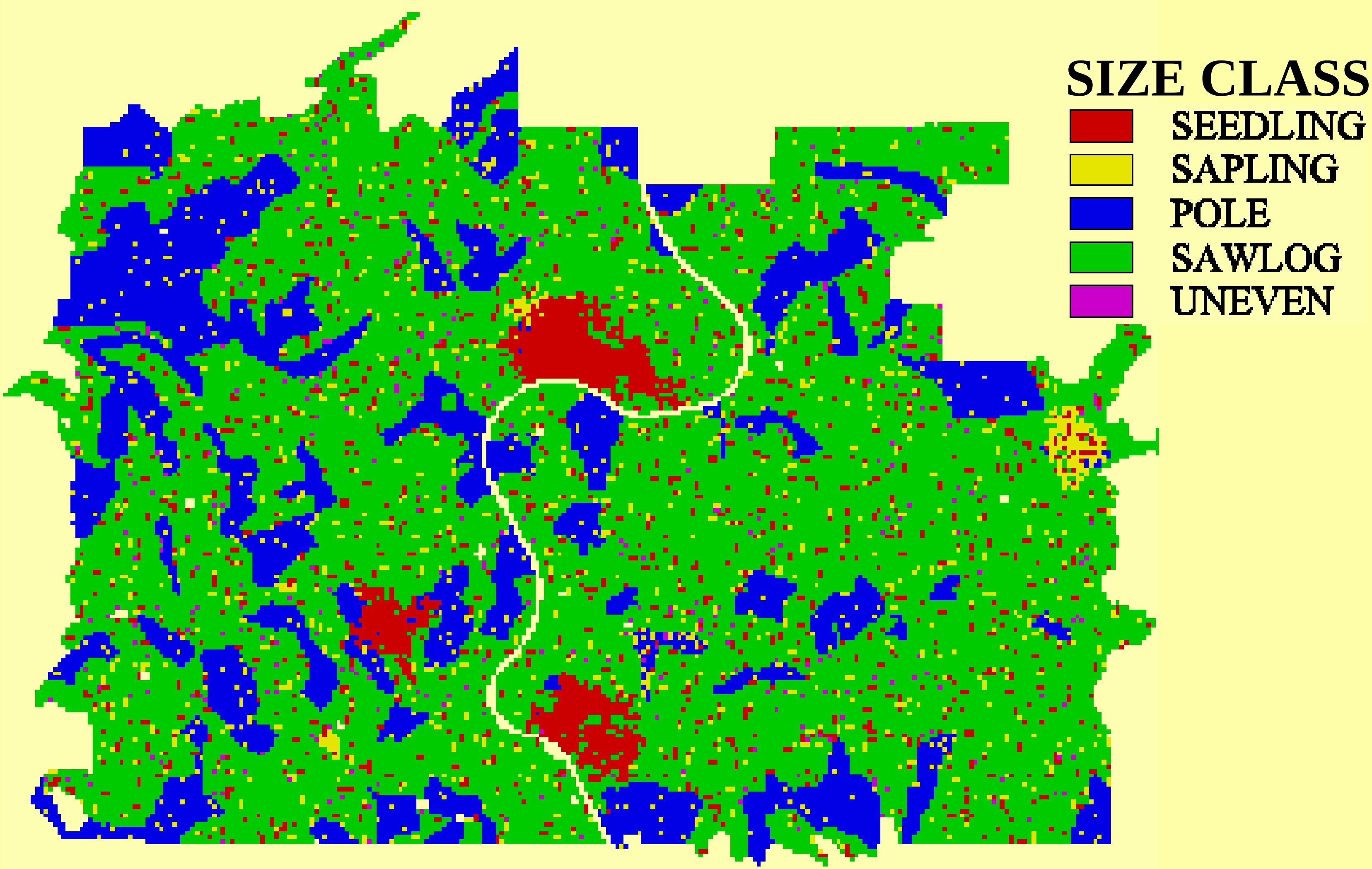
YEAR 80

EVEN-AGED INTENSIVE MANAGEMENT



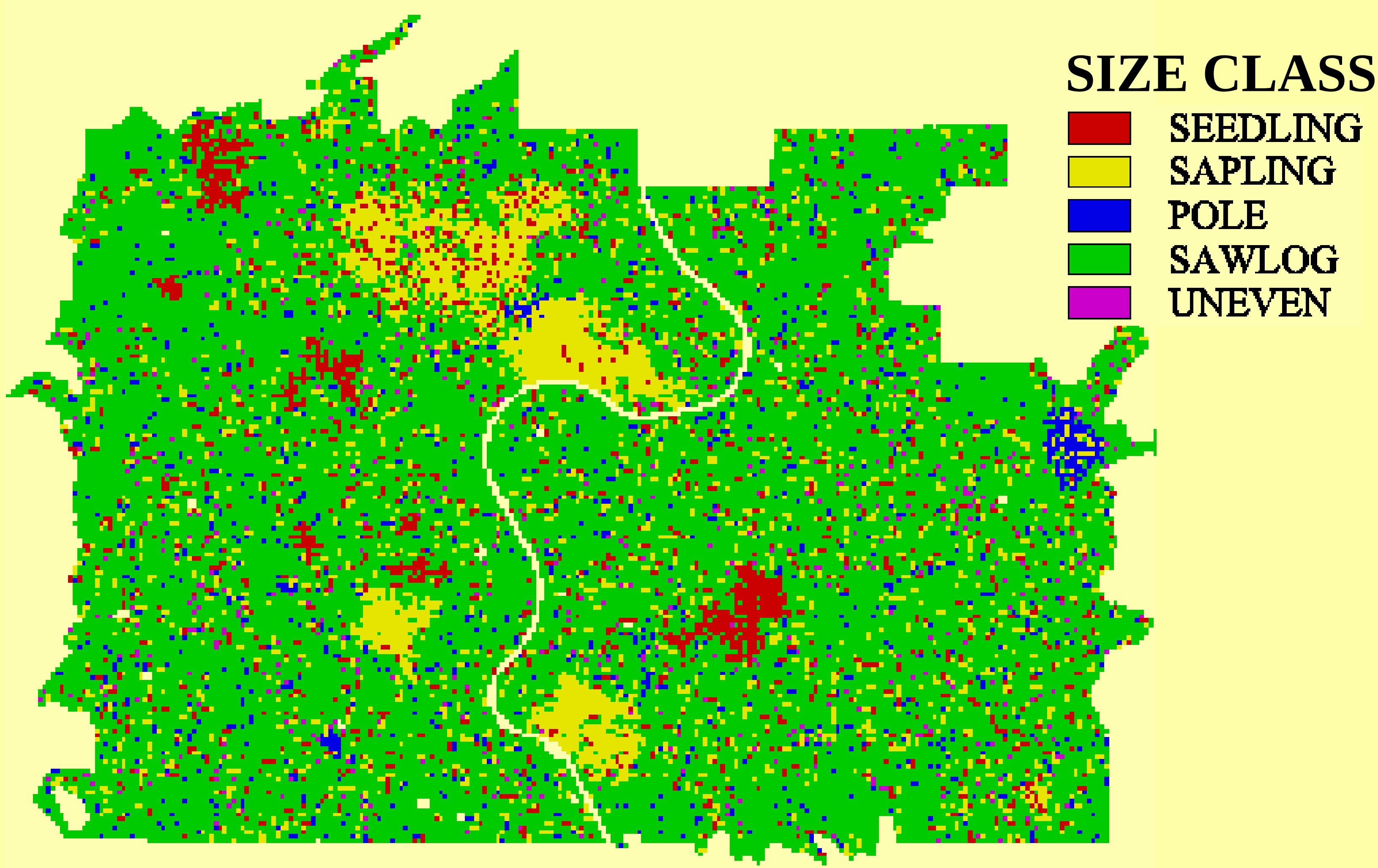
YEAR 100

UNEVEN-AGED MANAGEMENT



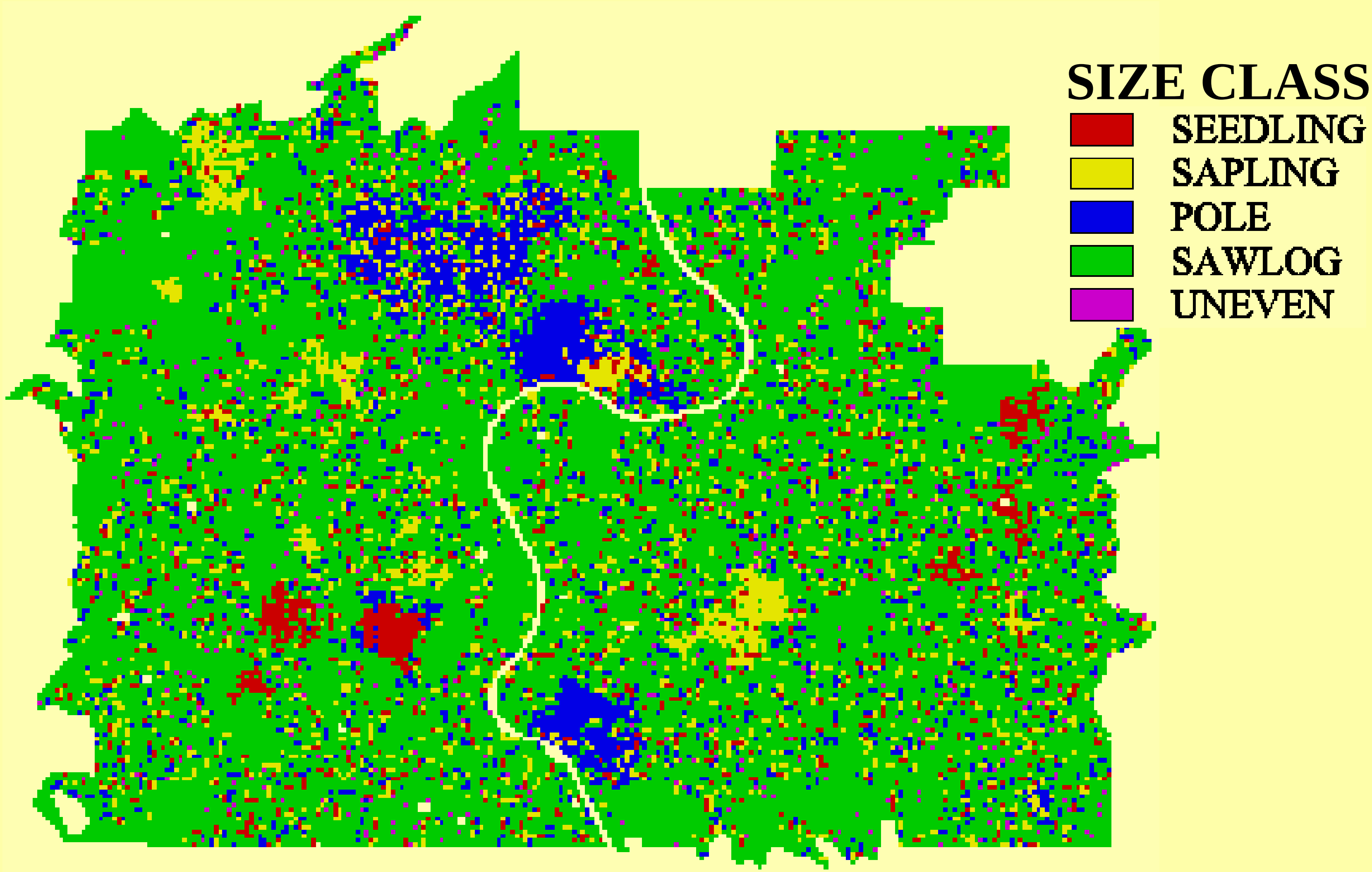
YEAR 20

UNEVEN-AGED MANAGEMENT



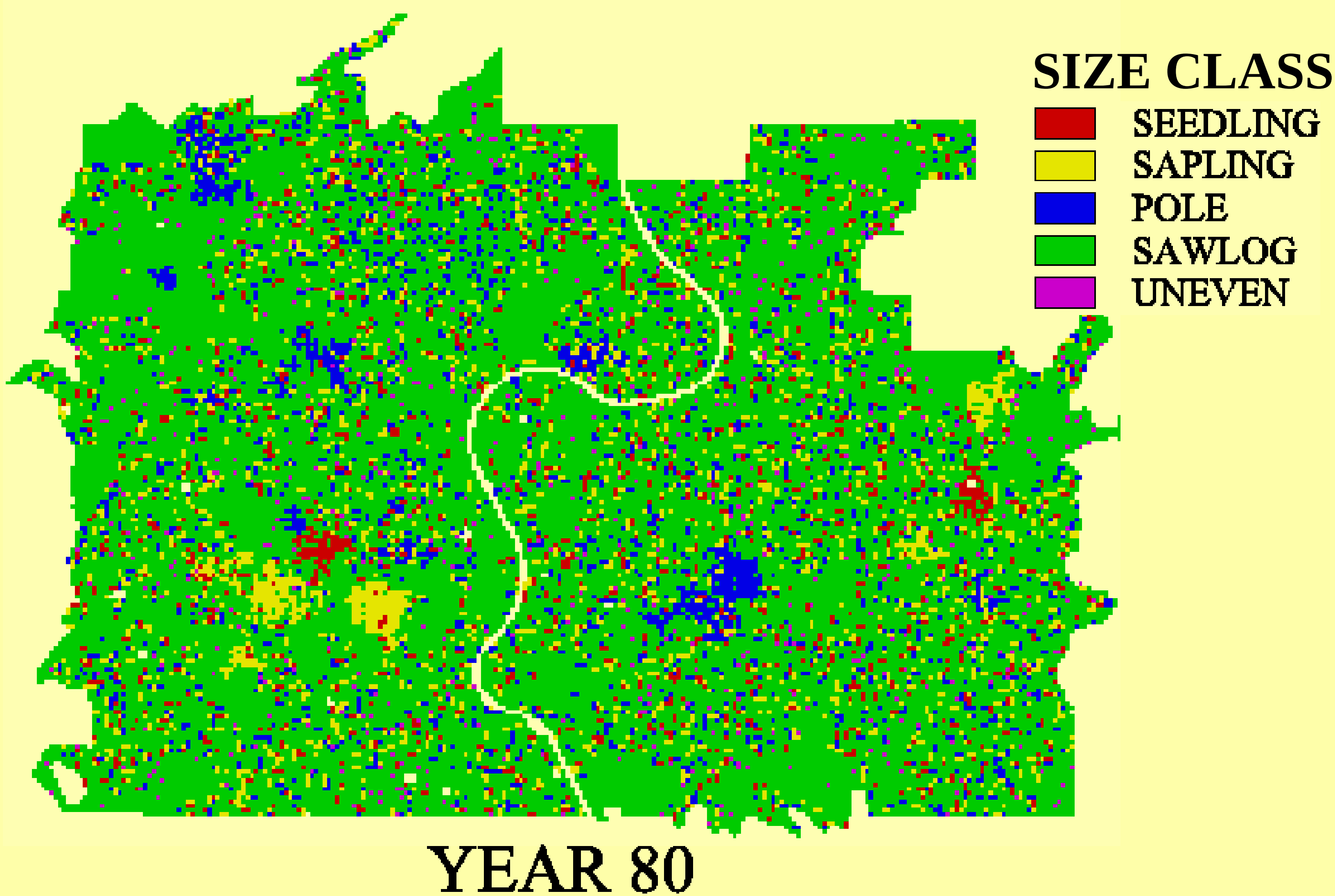
YEAR 40

UNEVEN-AGED MANAGEMENT

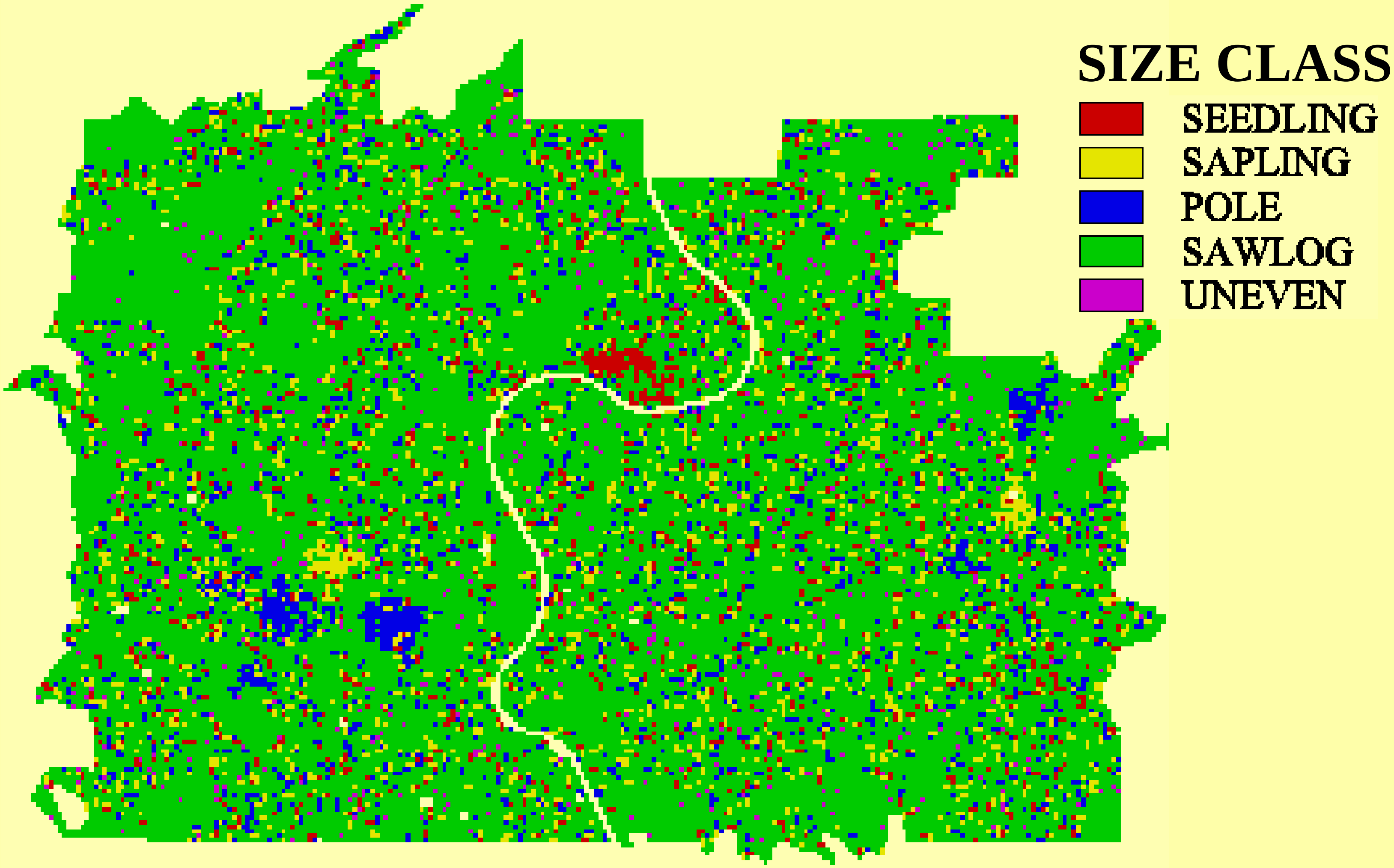


YEAR 60

UNEVEN-AGED MANAGEMENT

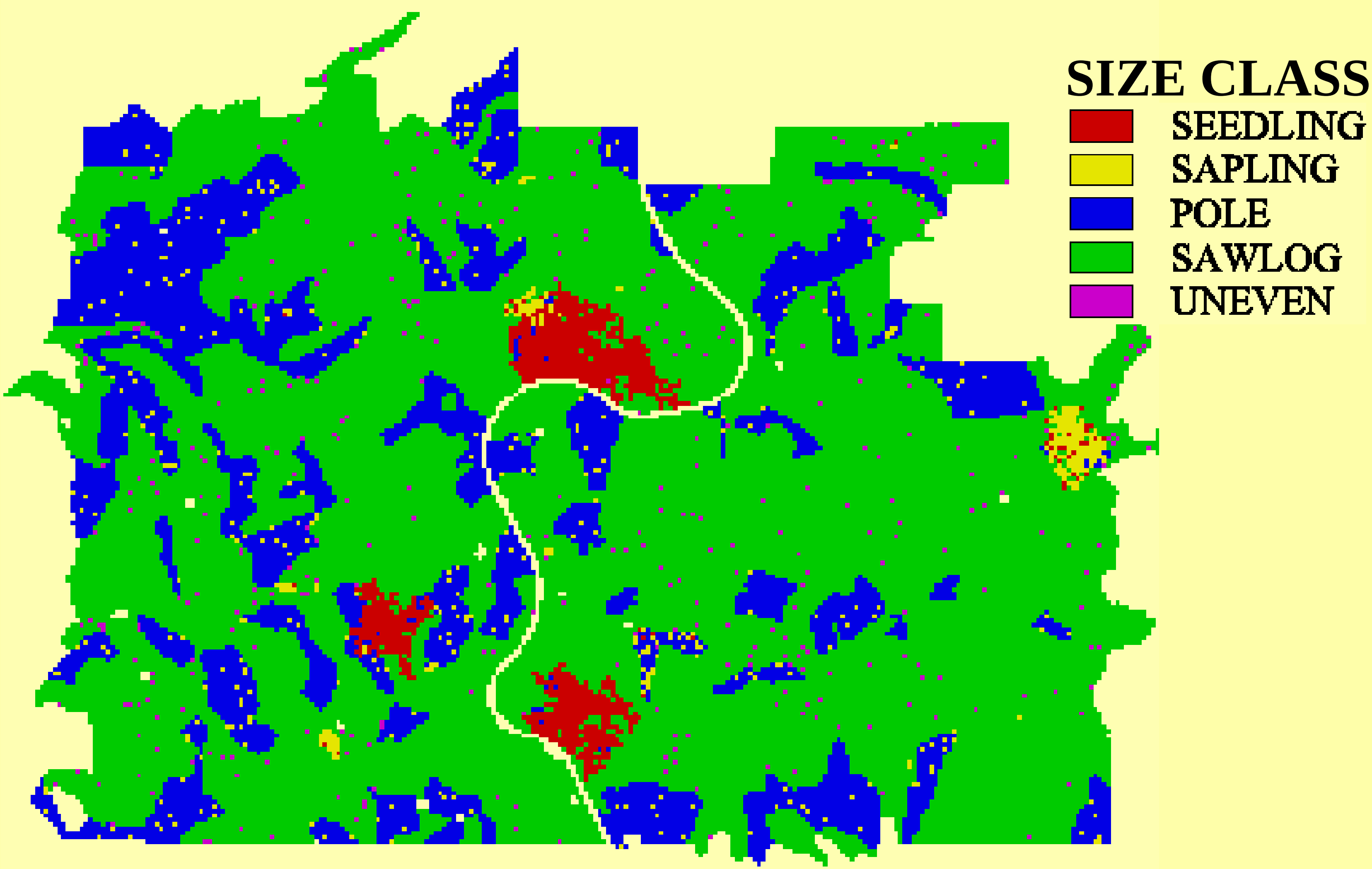


UNEVEN-AGED MANAGEMENT



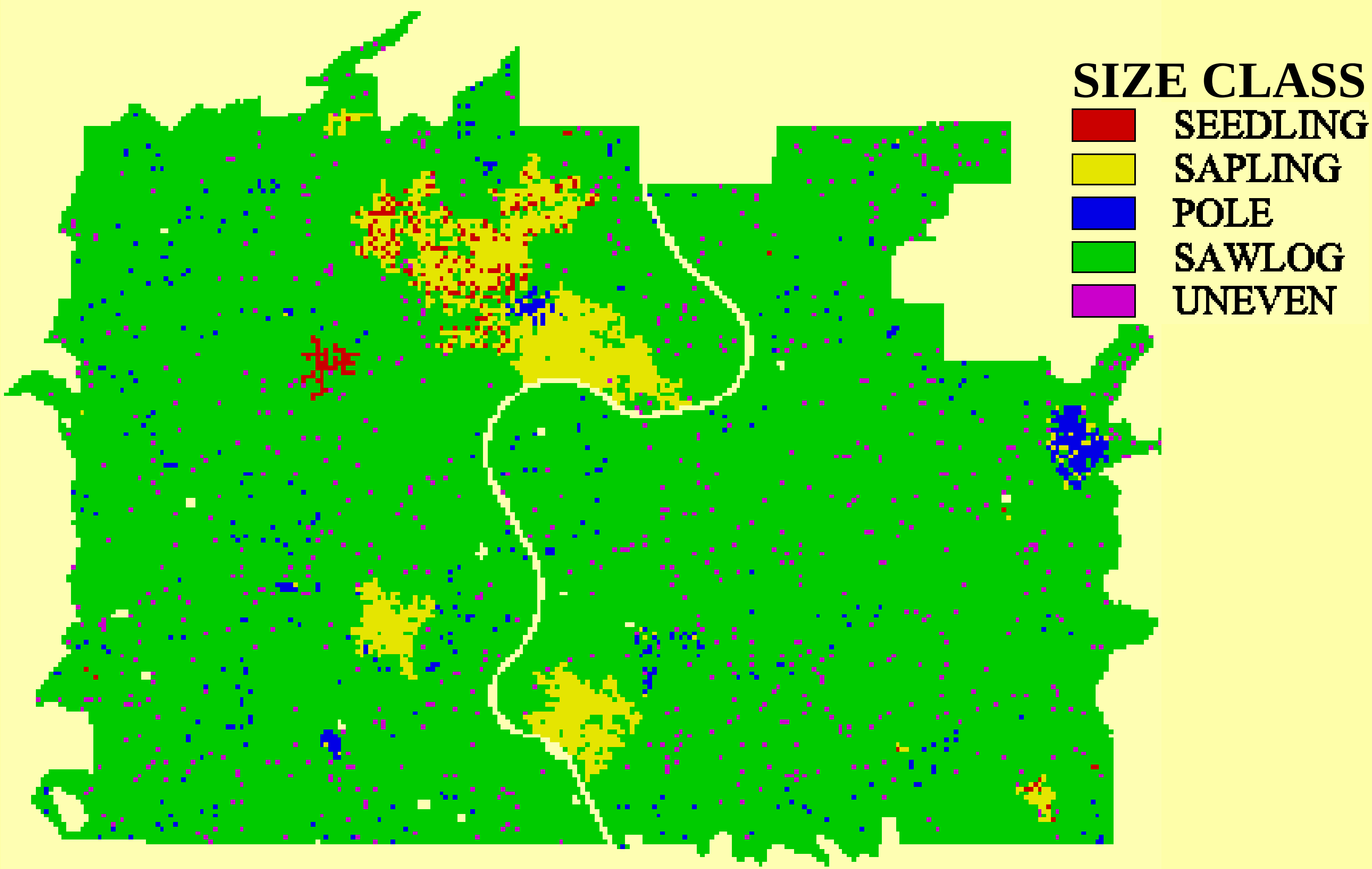
YEAR 100

NO HARVEST MANAGEMENT



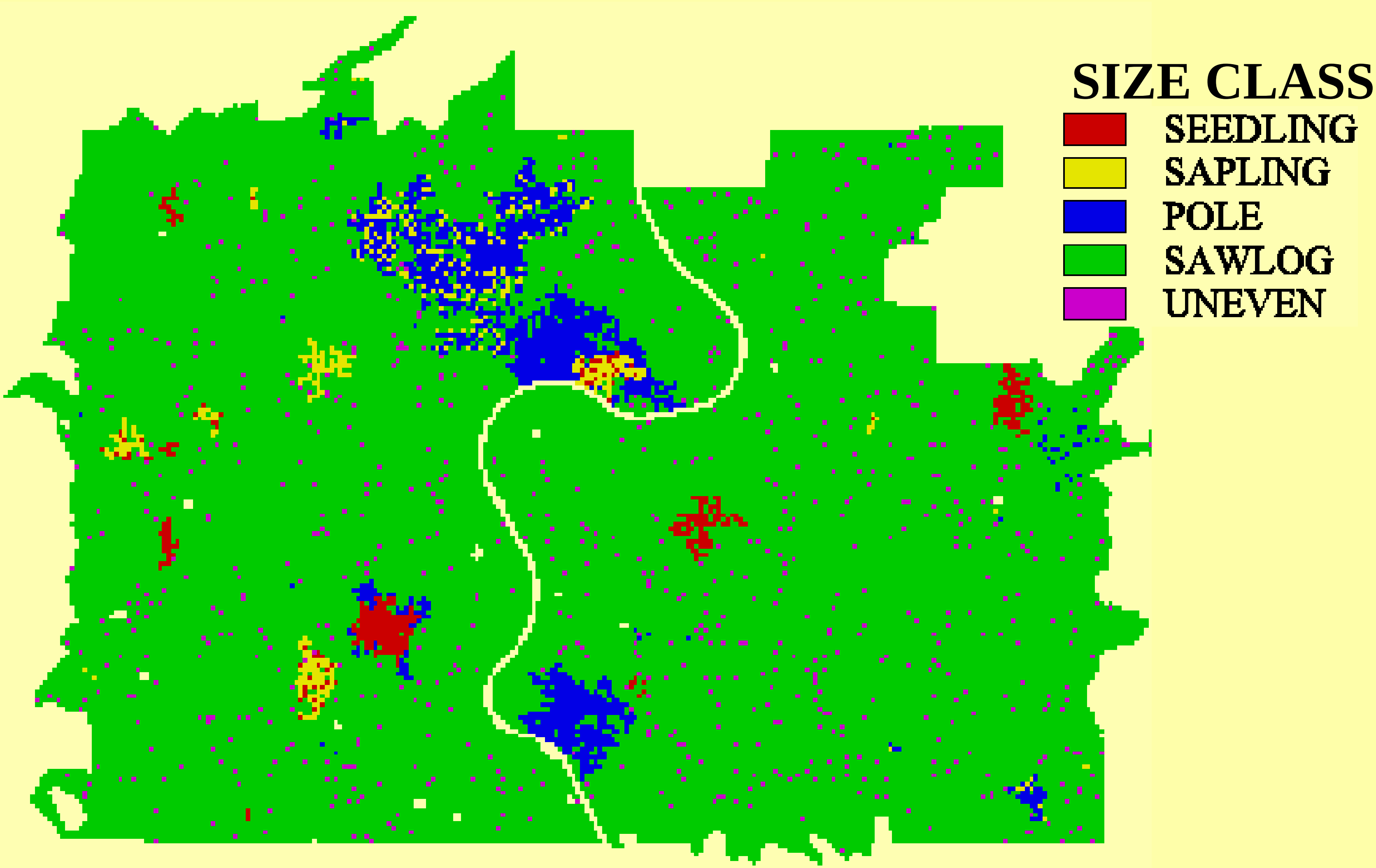
YEAR 20

NO HARVEST MANAGEMENT



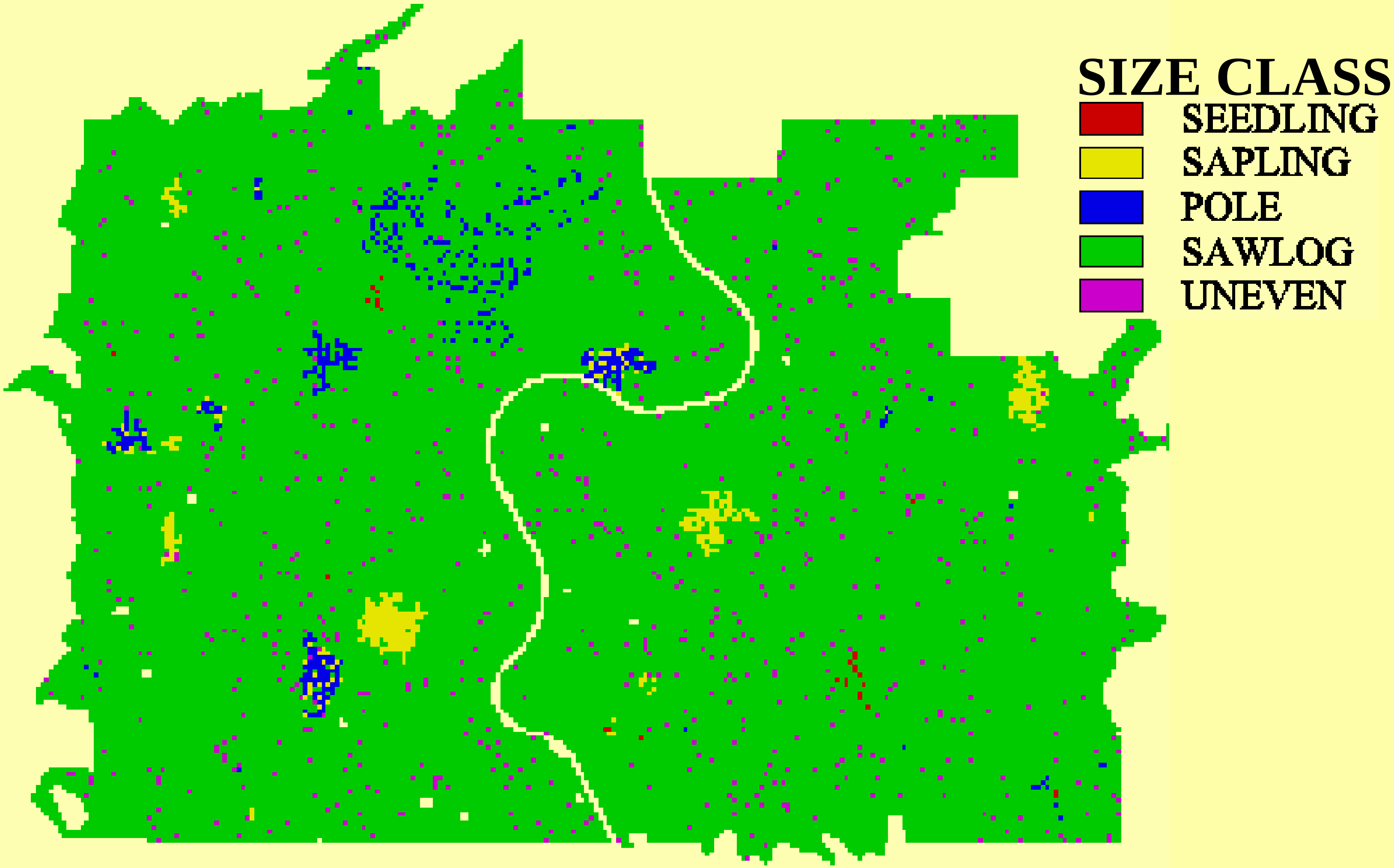
YEAR 40

NO HARVEST MANAGEMENT



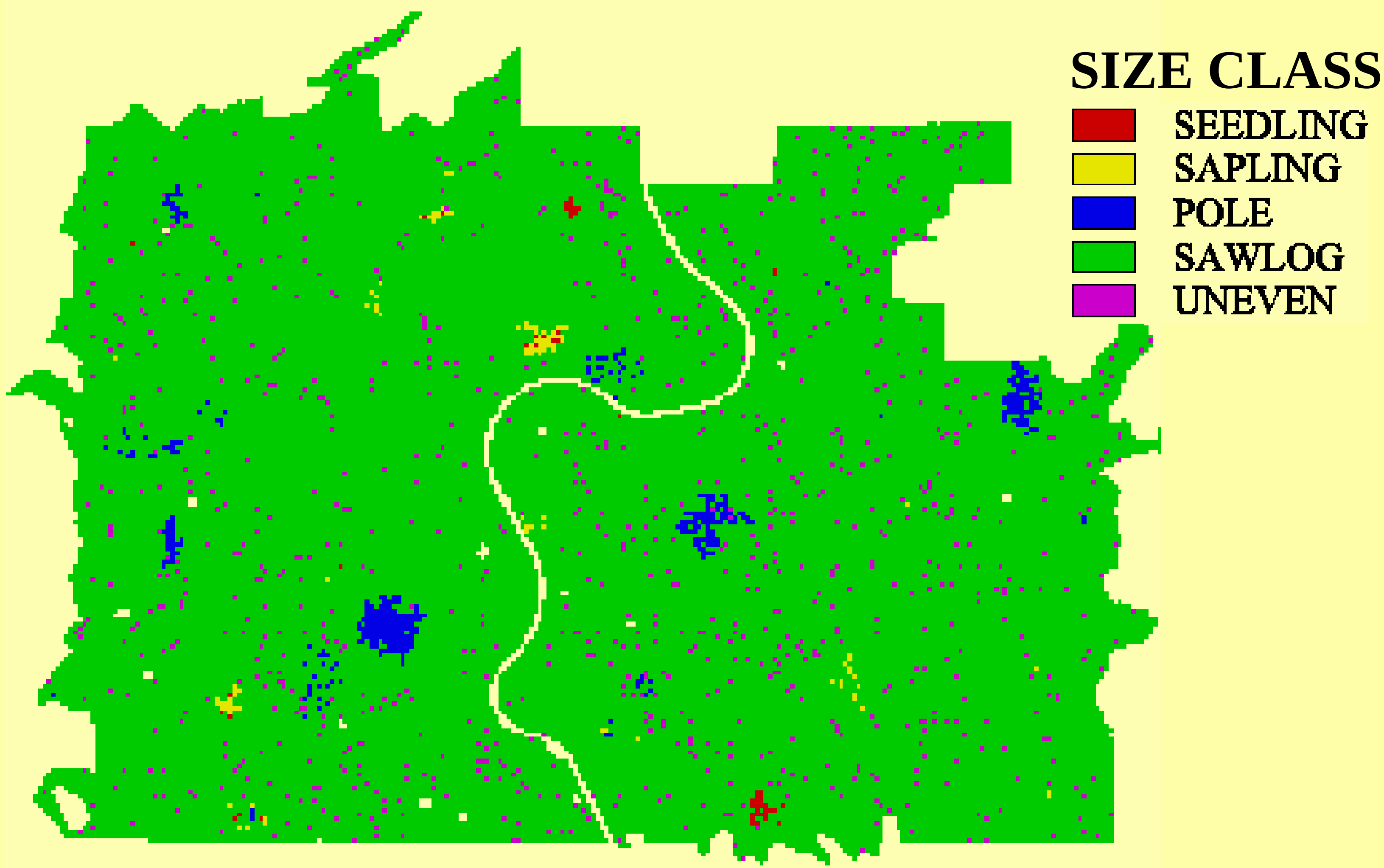
YEAR 60

NO HARVEST MANAGEMENT

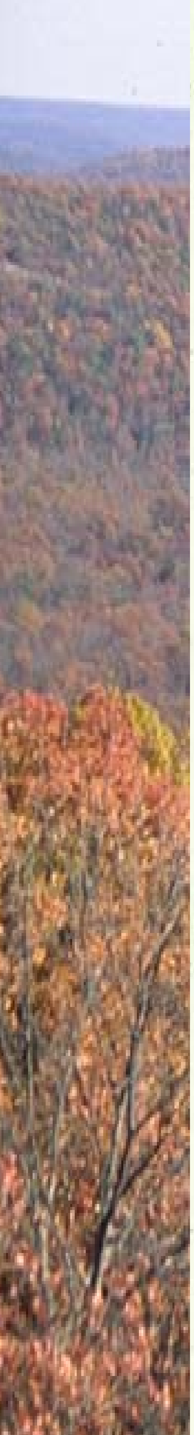


YEAR 80

NO HARVEST MANAGEMENT



YEAR 100



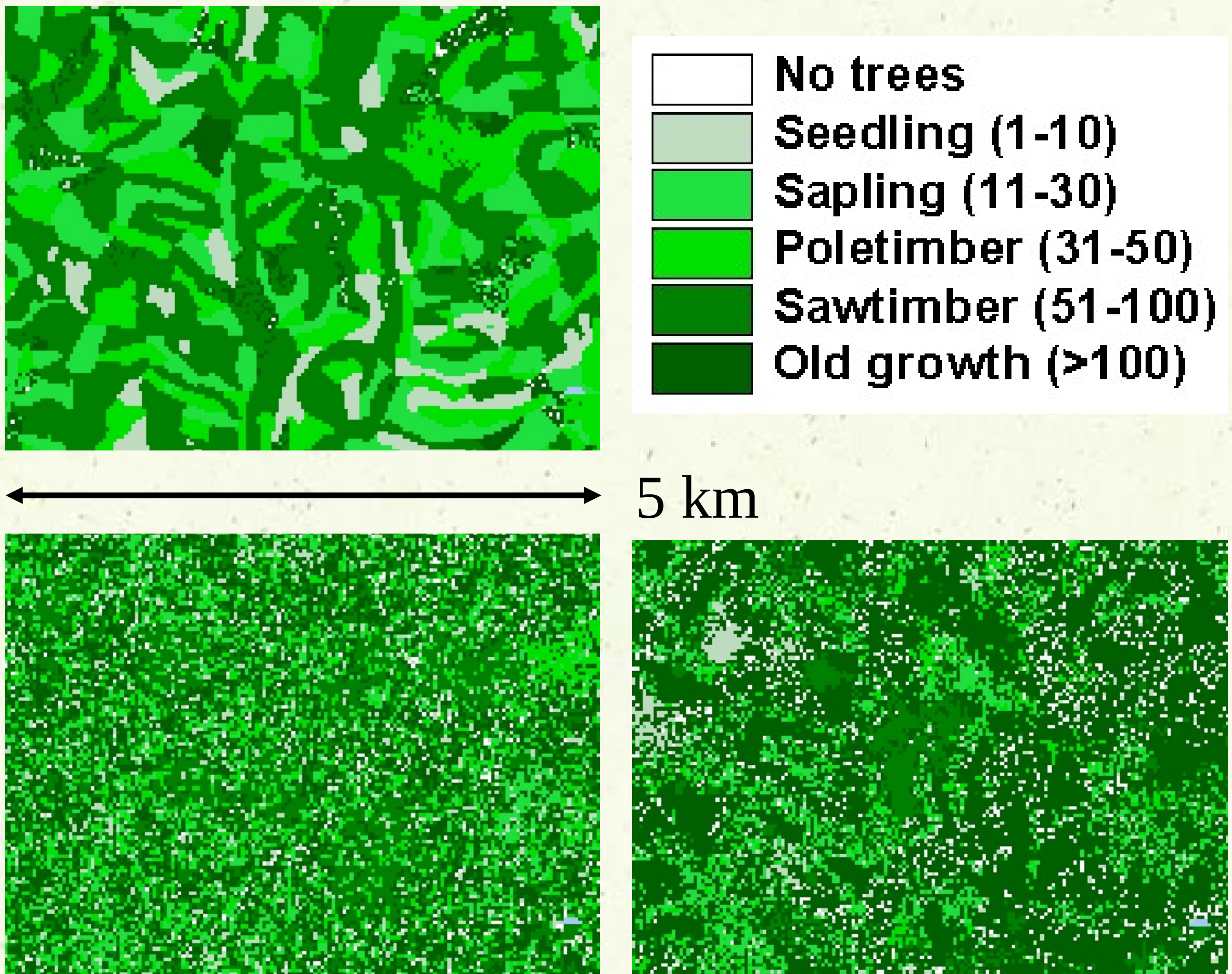
Output Maps for Each Decade of Simulation

- **Tree species (or dominance)**
- **Vegetation age class**
- **Fire damage**
- **Wind damage**
- **Type and location of harvest**
- **Anything that can be derived from or linked to these characteristics**

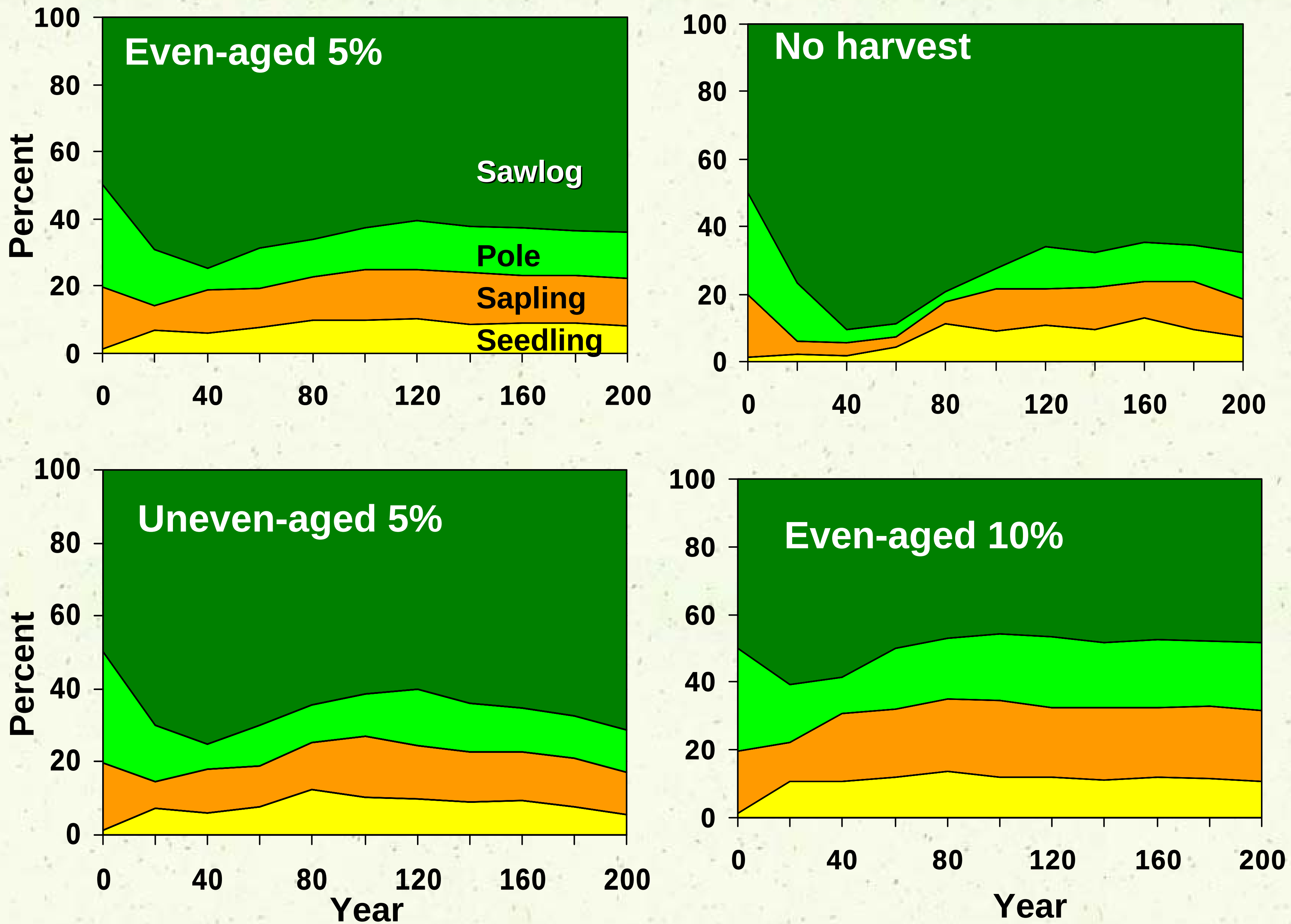
Tree size classes - year 100

Even 10%

Uneven 5%

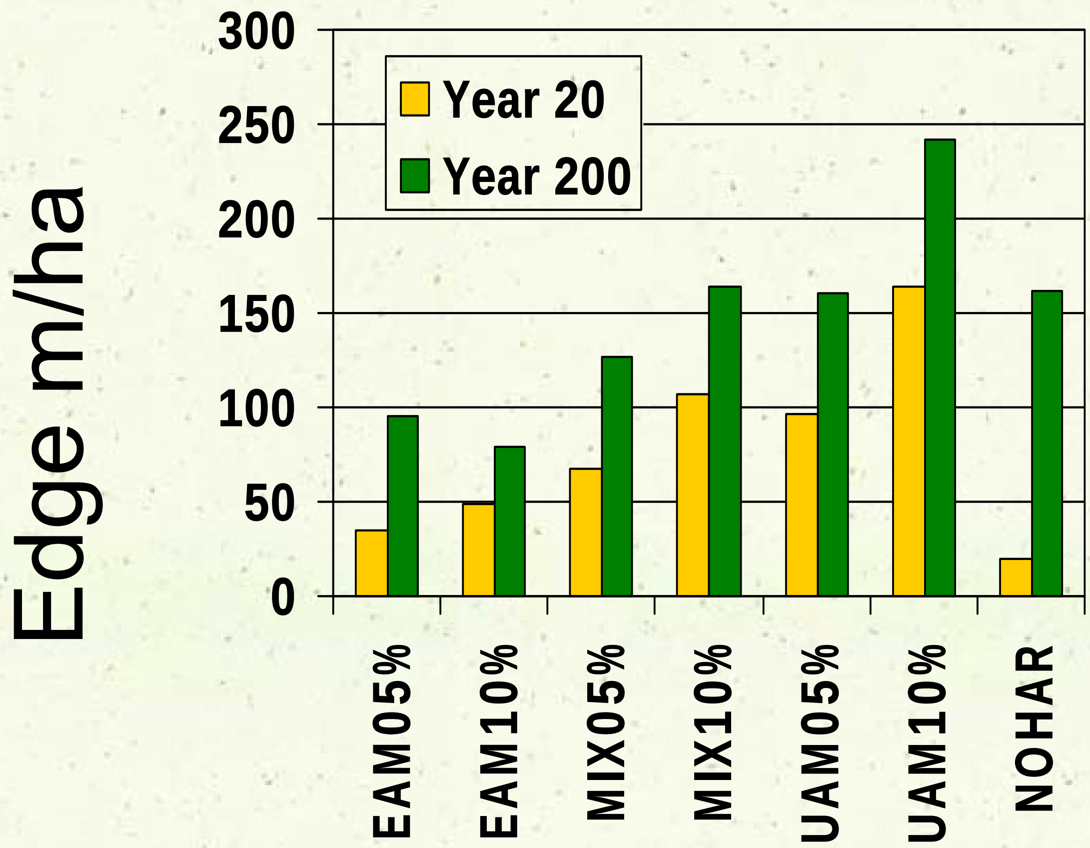


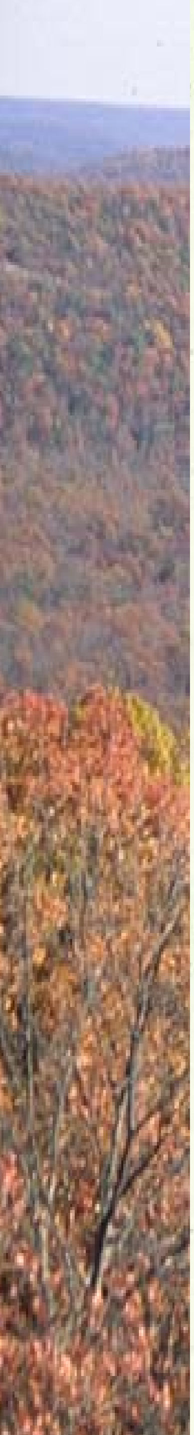
No Harv.



Even-aged 5%
Sawlog
Pole
Sapling
Seedling
No harvest
Uneven-aged 5%
Even-aged 10%
Percent
Percent
Year
Year
100
80
60
40
20
0
0
40
80
120
160
200

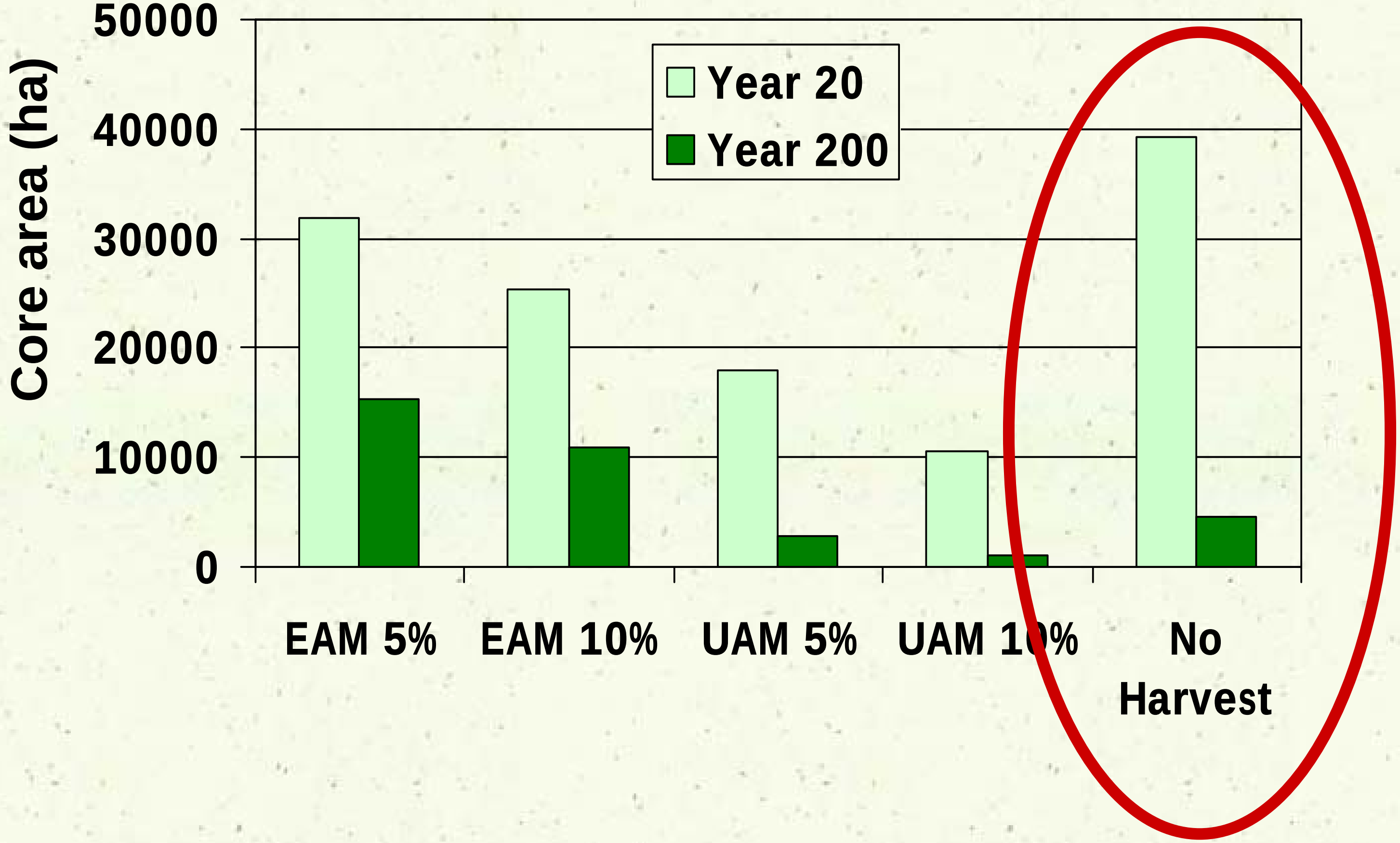
Length of Edge





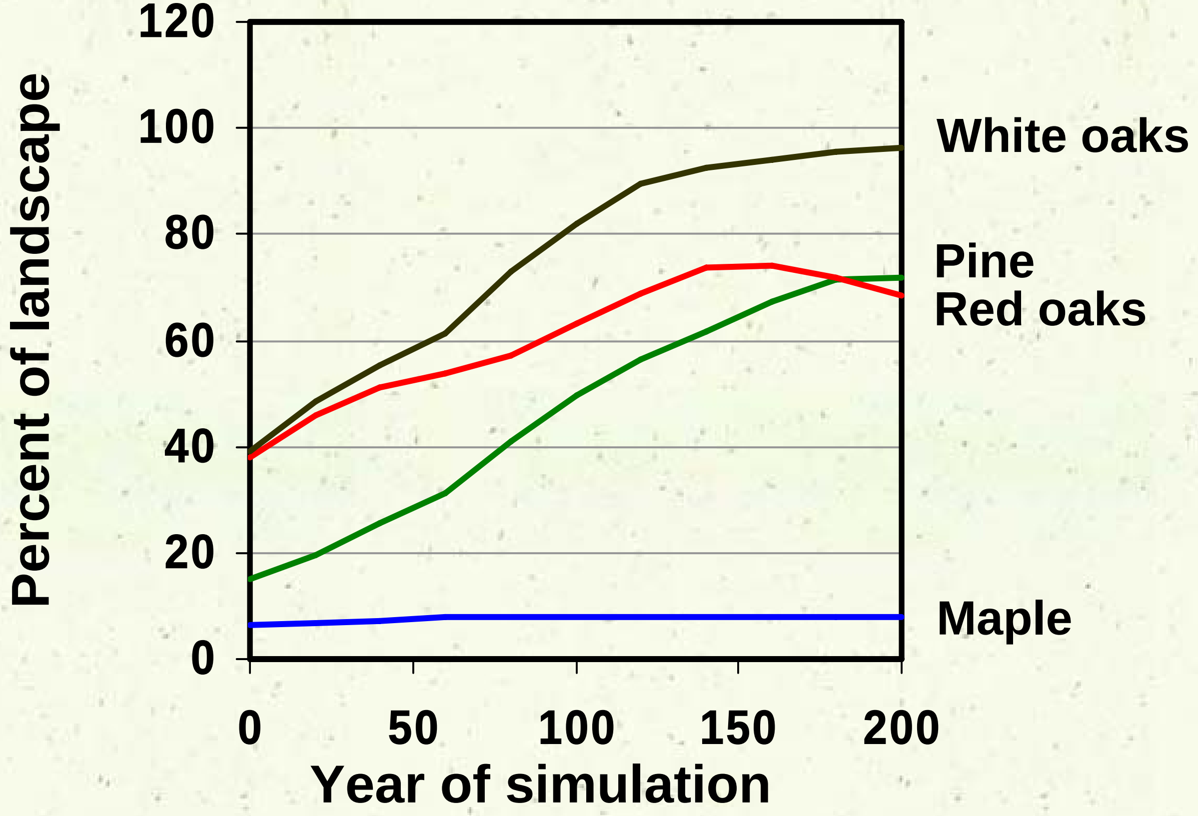
Core Area

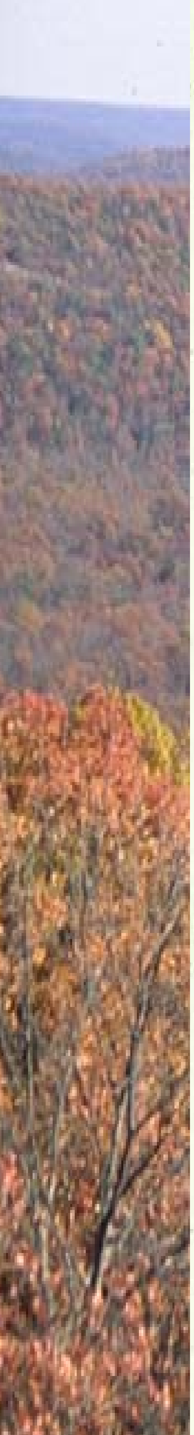
$\geq$ 50 years old and 60 M from edge

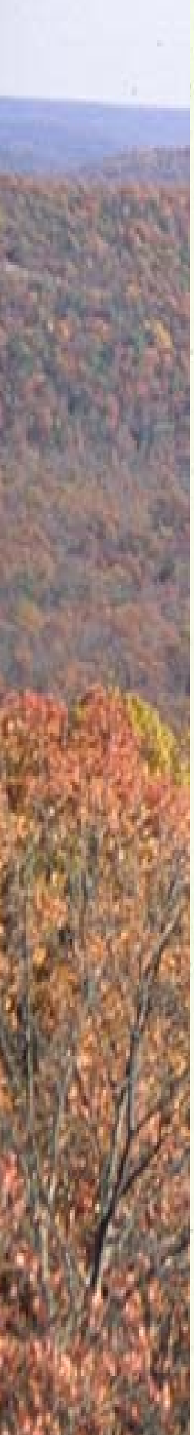


Species group occurrence

Uneven-aged management
5% harvest alternative

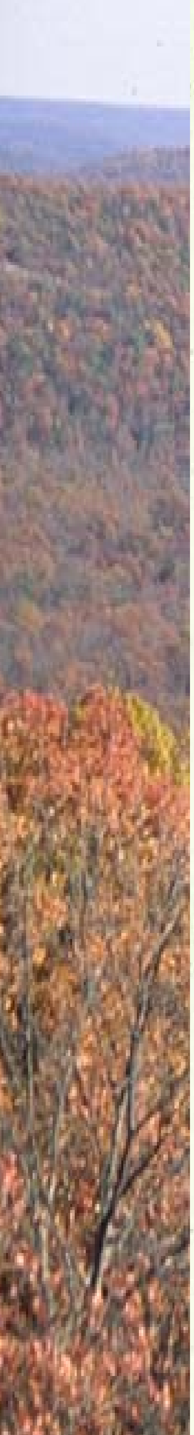






Strengths

- Provides the big picture. Great tool to view large scale forest change
- Compare management alternatives visually
  - Generates discussion with public and across disciplines
- Model vegetation succession
- Analyze projected landscape characteristics
- Compare landscape statistics among alternatives
- Assess change over time.
- Operational tool to guide multiple use forest planning
- Make linkages to other resources
  - Wildlife Mast Timber
  - Down wood Cavities
- Enthusiastic developer and user groups



Limitations

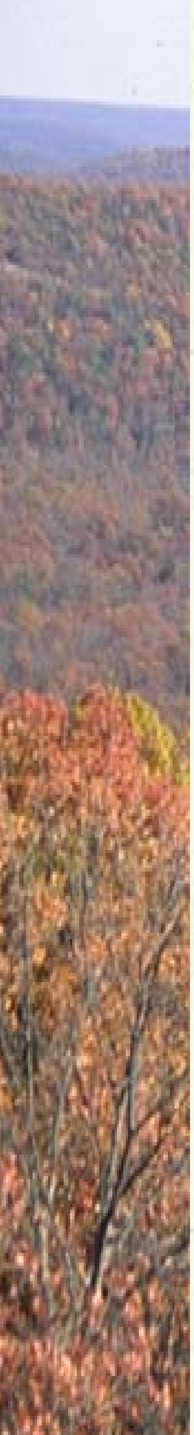
- **Not suitable for site-specific planning**
- **Maps create tendency to take results too literally**
- **Probabilistic model (+/-) (repeated runs)**
- **Requires significant GIS capability**
- **Big effort to learn to use it (getting better)**
- **Requires maps of land units and stands for most harvest simulations**
- **Needs lots of computing horsepower for big landscapes**

Wildlife modeling process

LANDIS → **Tree age and tree species maps**

↓

Other coverages → **Habitat models**

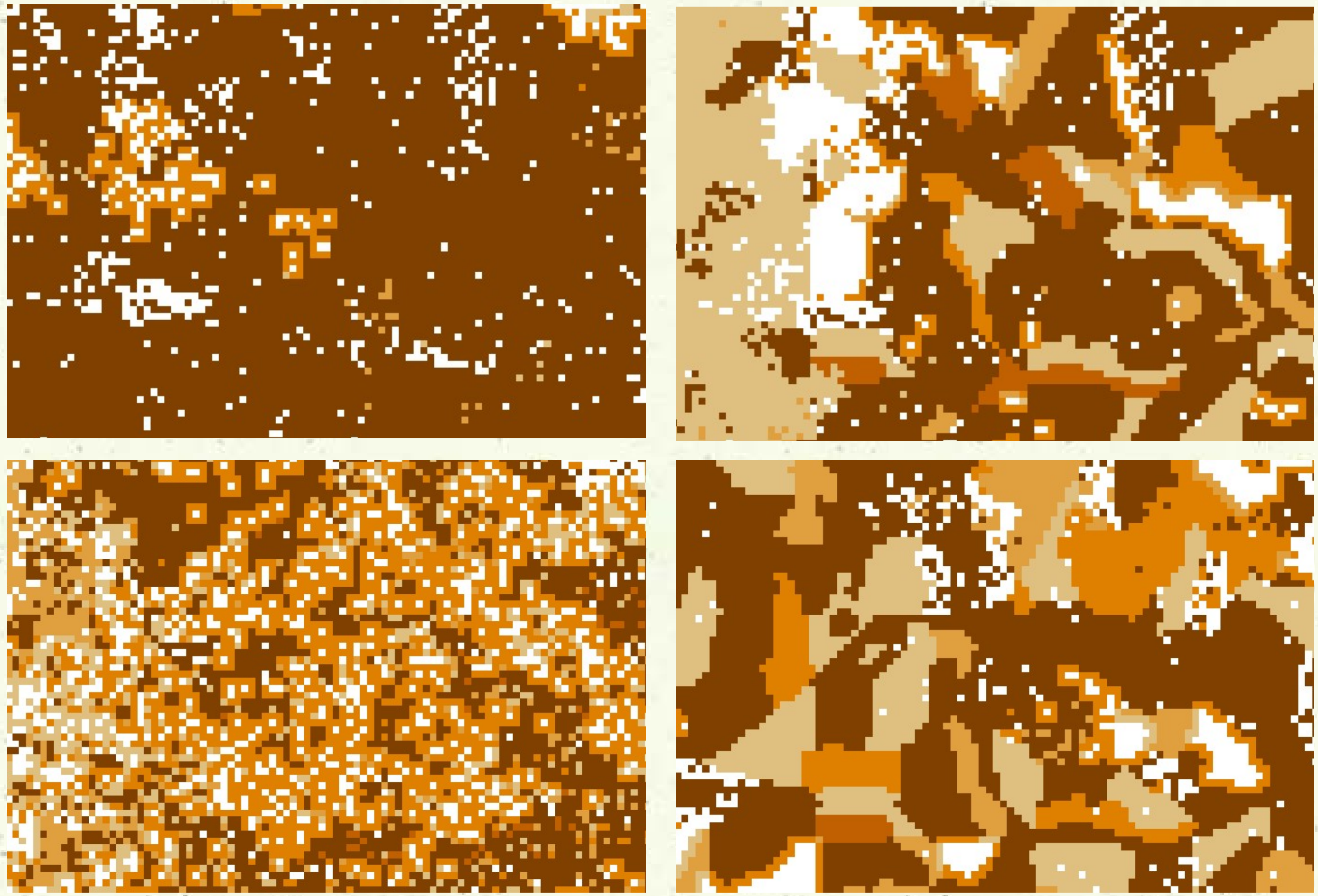


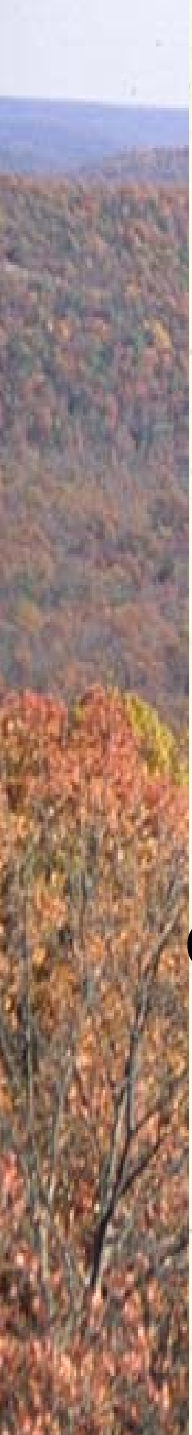
Ovenbird Habitat Suitability

No harvest | **Even-age 10%**

Year 50

Year 200





Wildlife modeling process

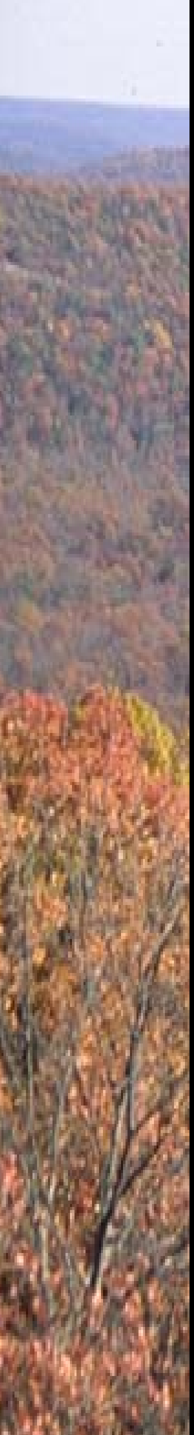
LANDIS → Tree age and tree species maps

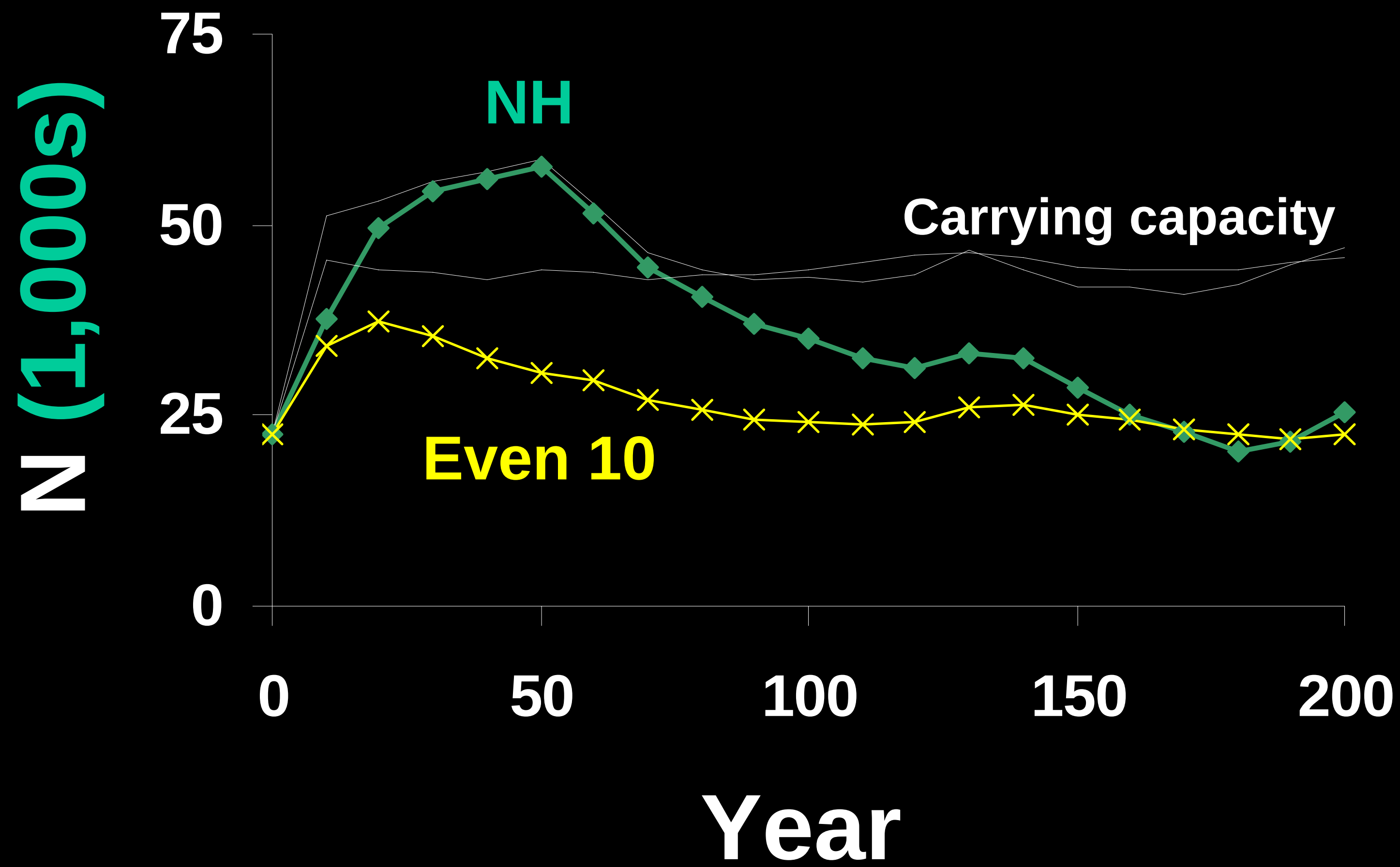
Tree age and tree species maps ↓ Habitat models

Other coverages → Habitat models → Habitat suitability maps

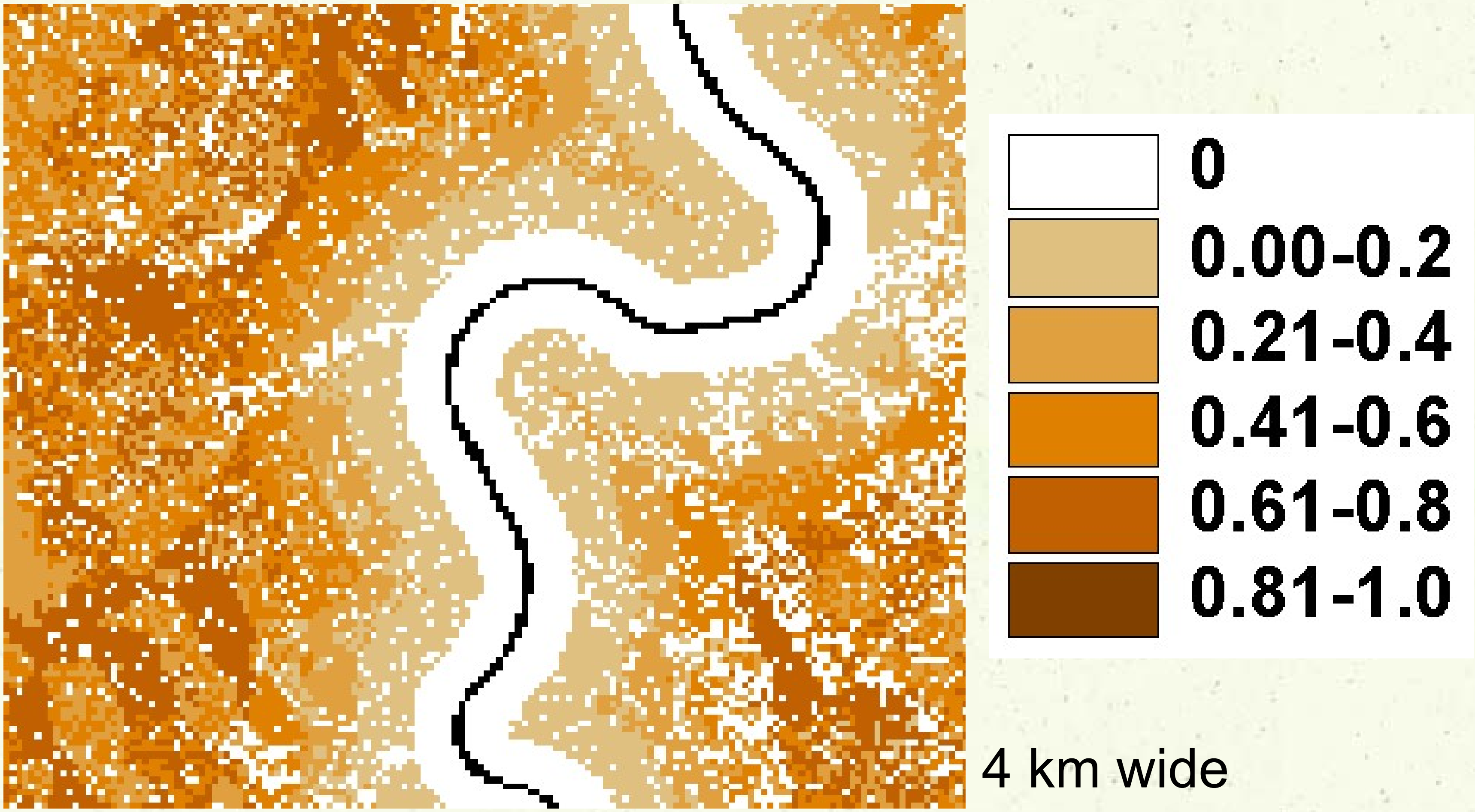
Habitat suitability maps ↓ Viability modeling

Ovenbird viability

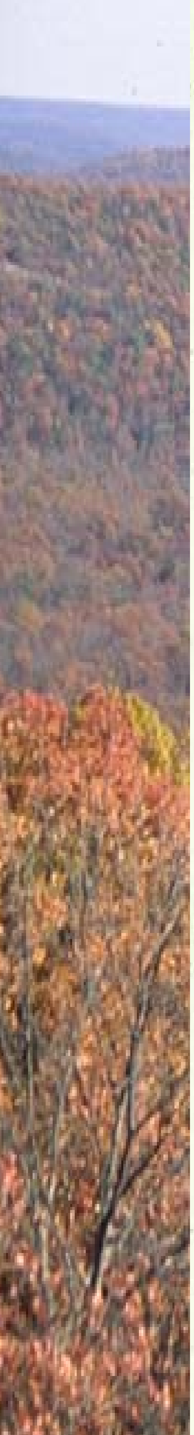




Black Bear Habitat Suitability

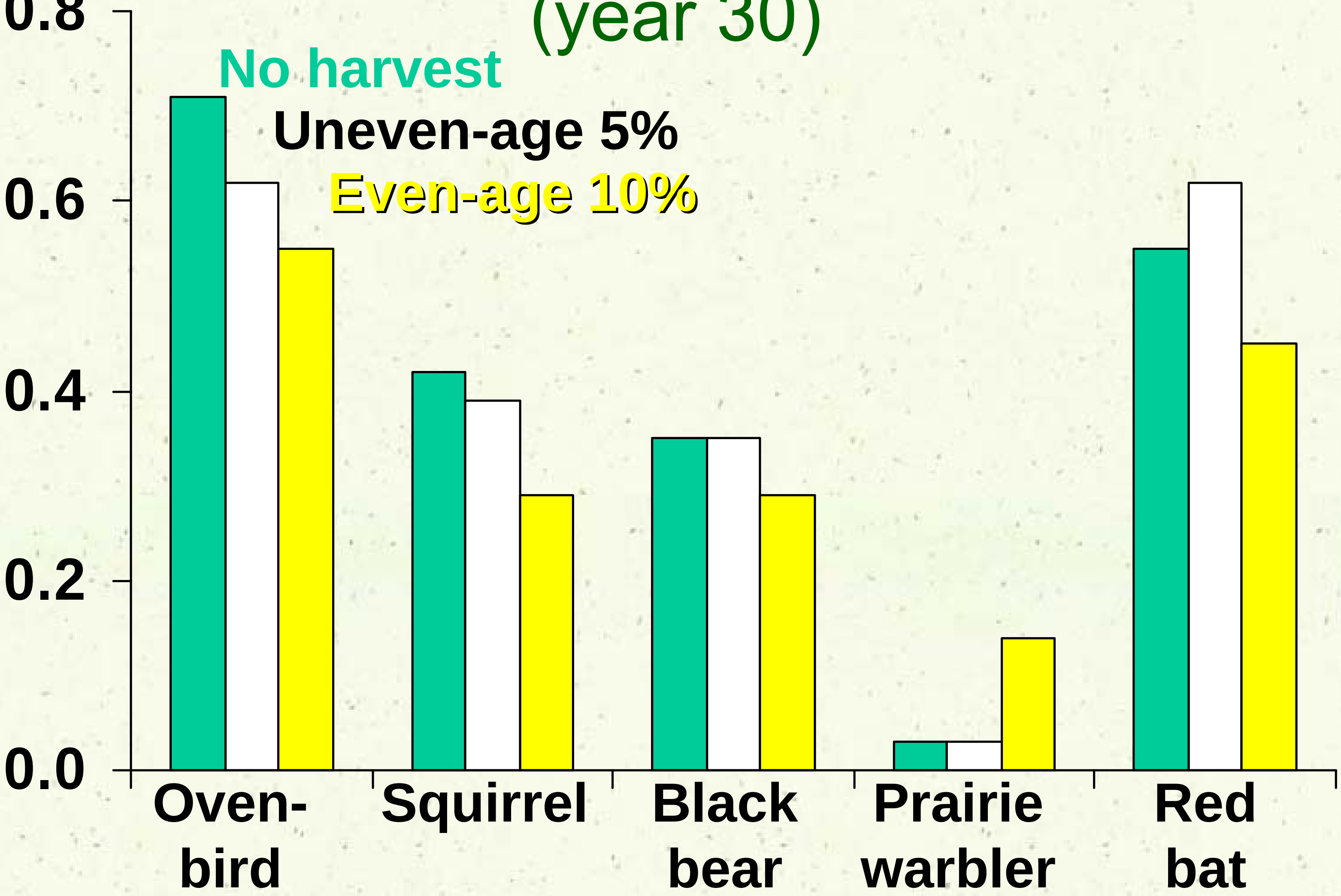


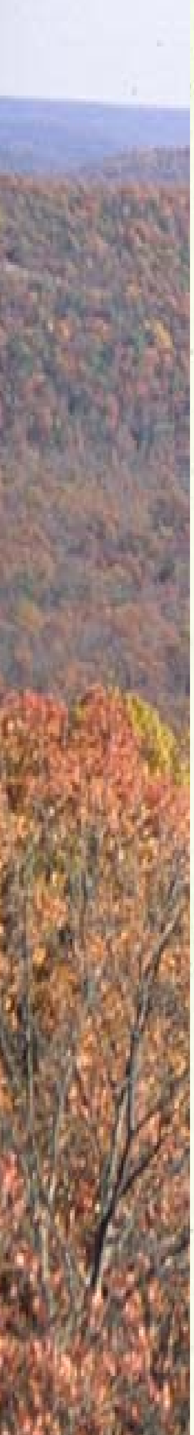
4 km wide



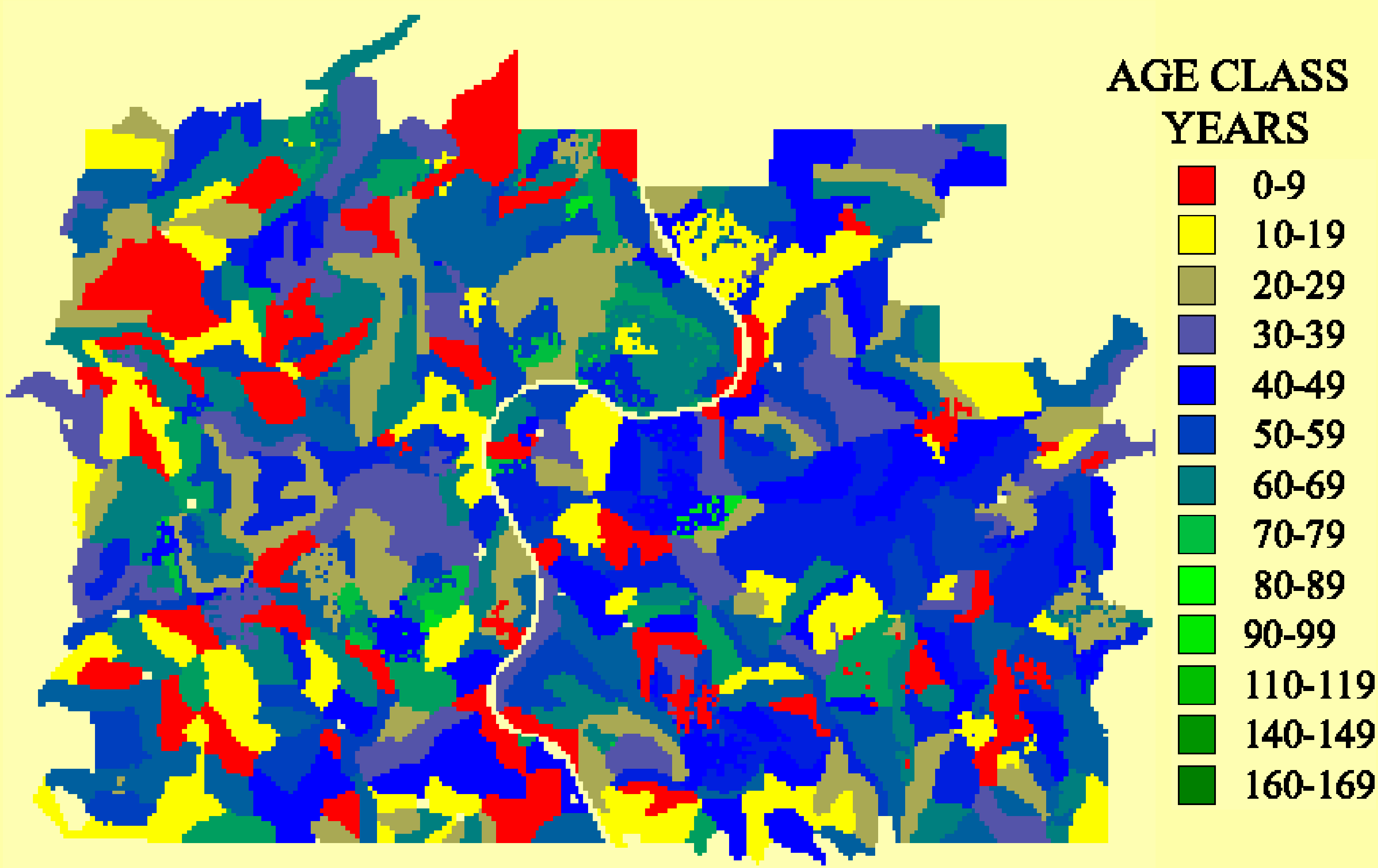
Mean HSI values

(year 30)



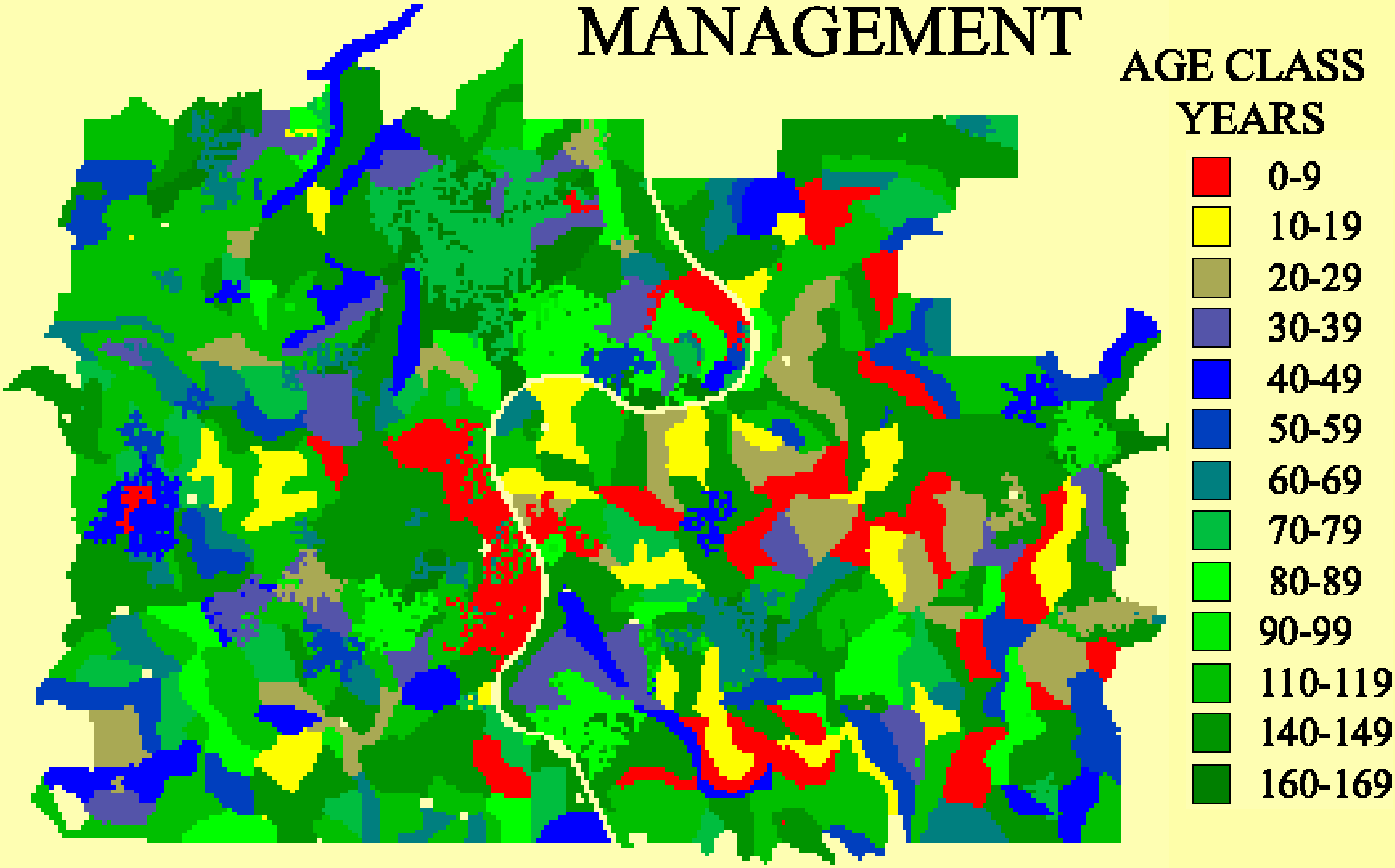


EVEN-AGED INTENSIVE MANAGEMENT



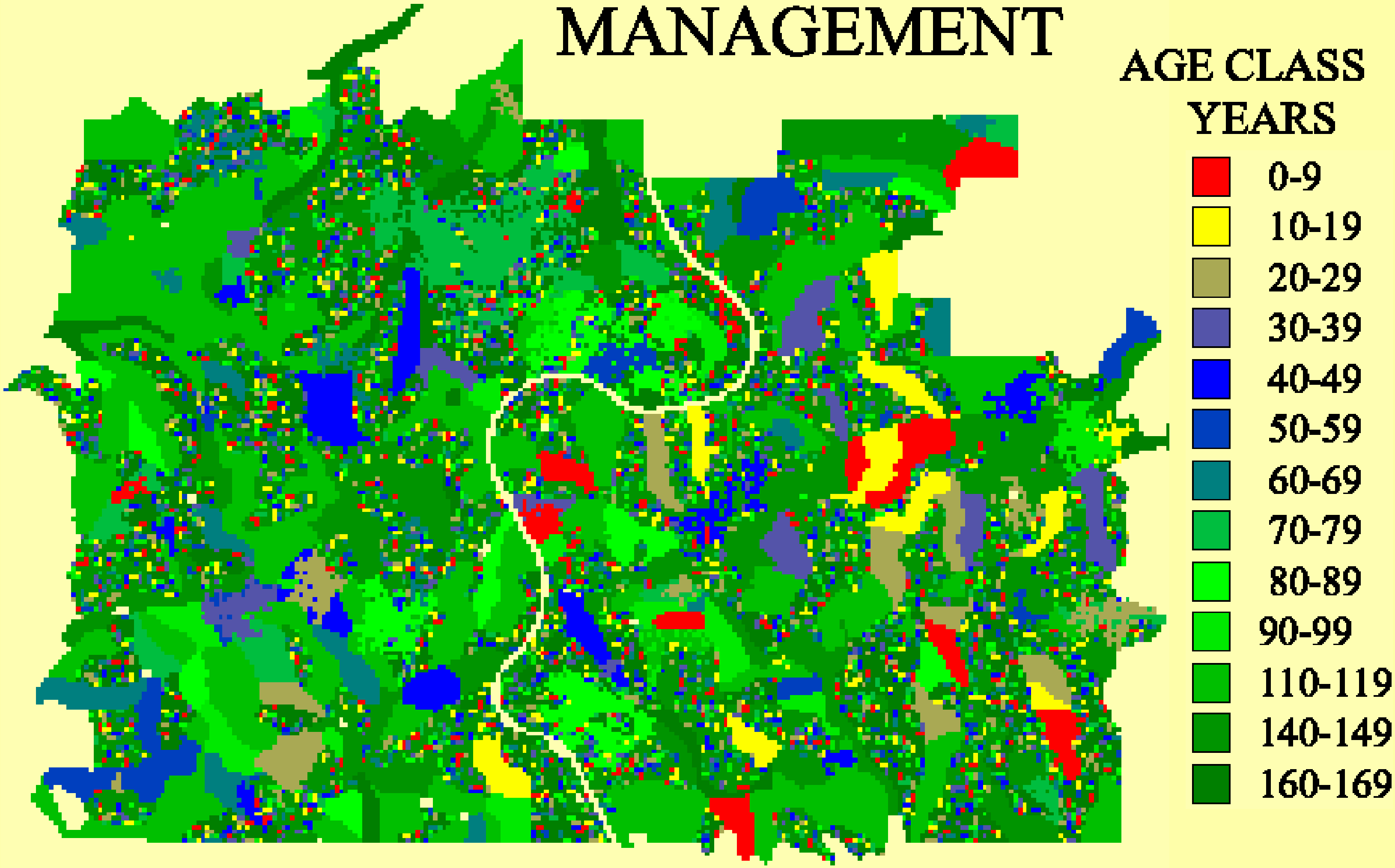
YEAR 100

EVEN-AGED LONG ROTATION MANAGEMENT



YEAR 100

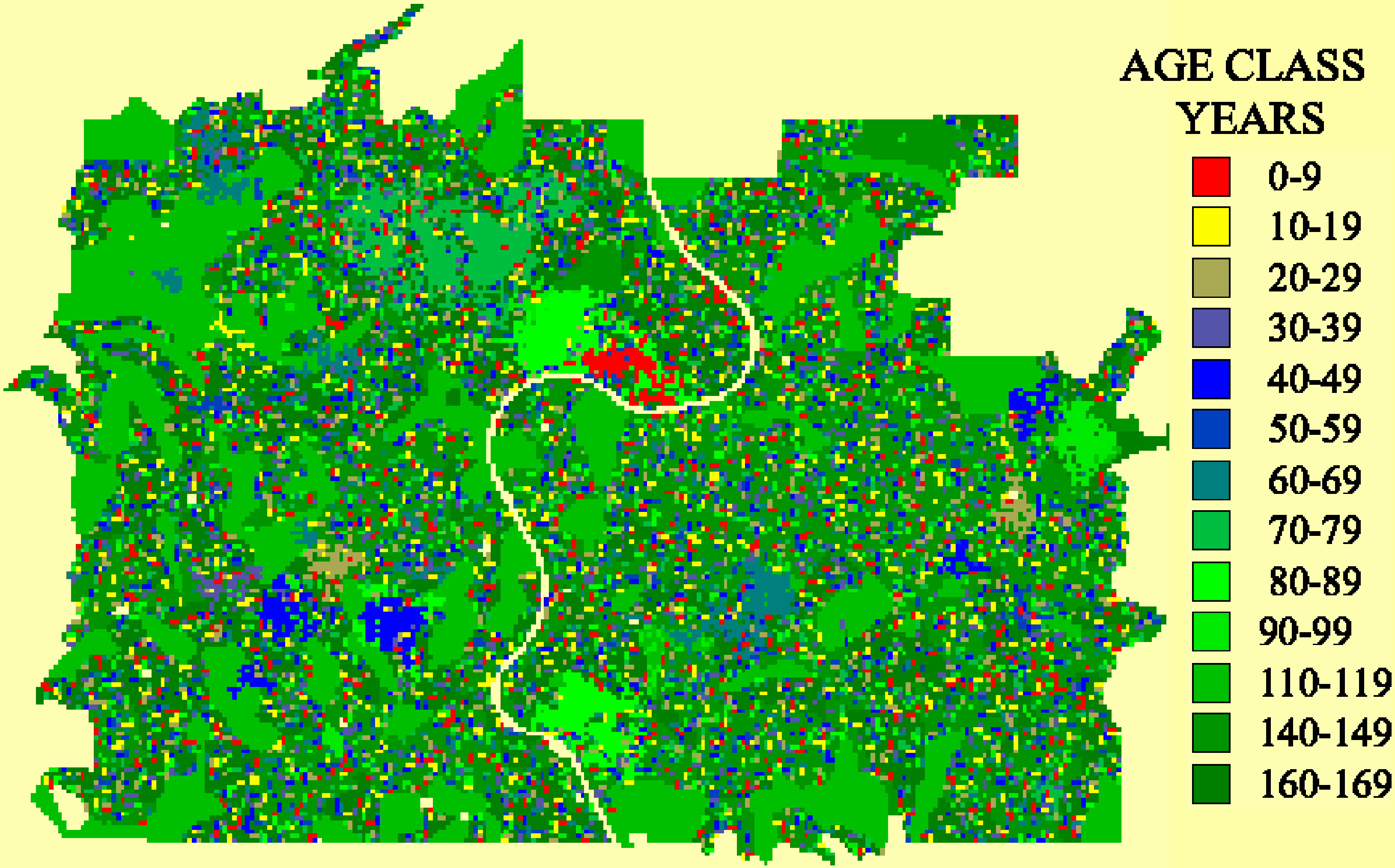
EVEN-AGED & UNEVEN-AGED MANAGEMENT



YEAR 100

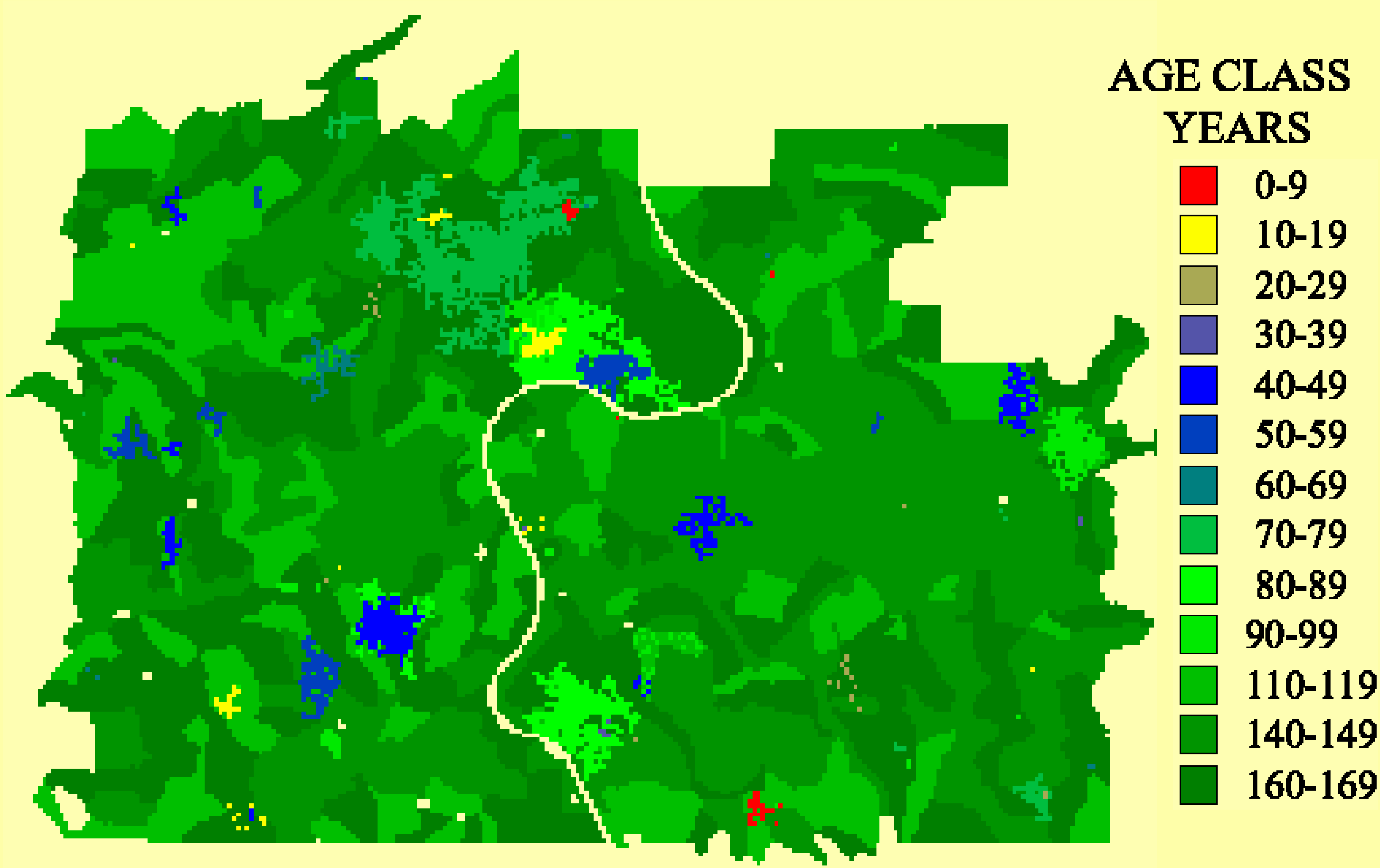
Habitat model links

UNEVEN-AGED MANAGEMENT



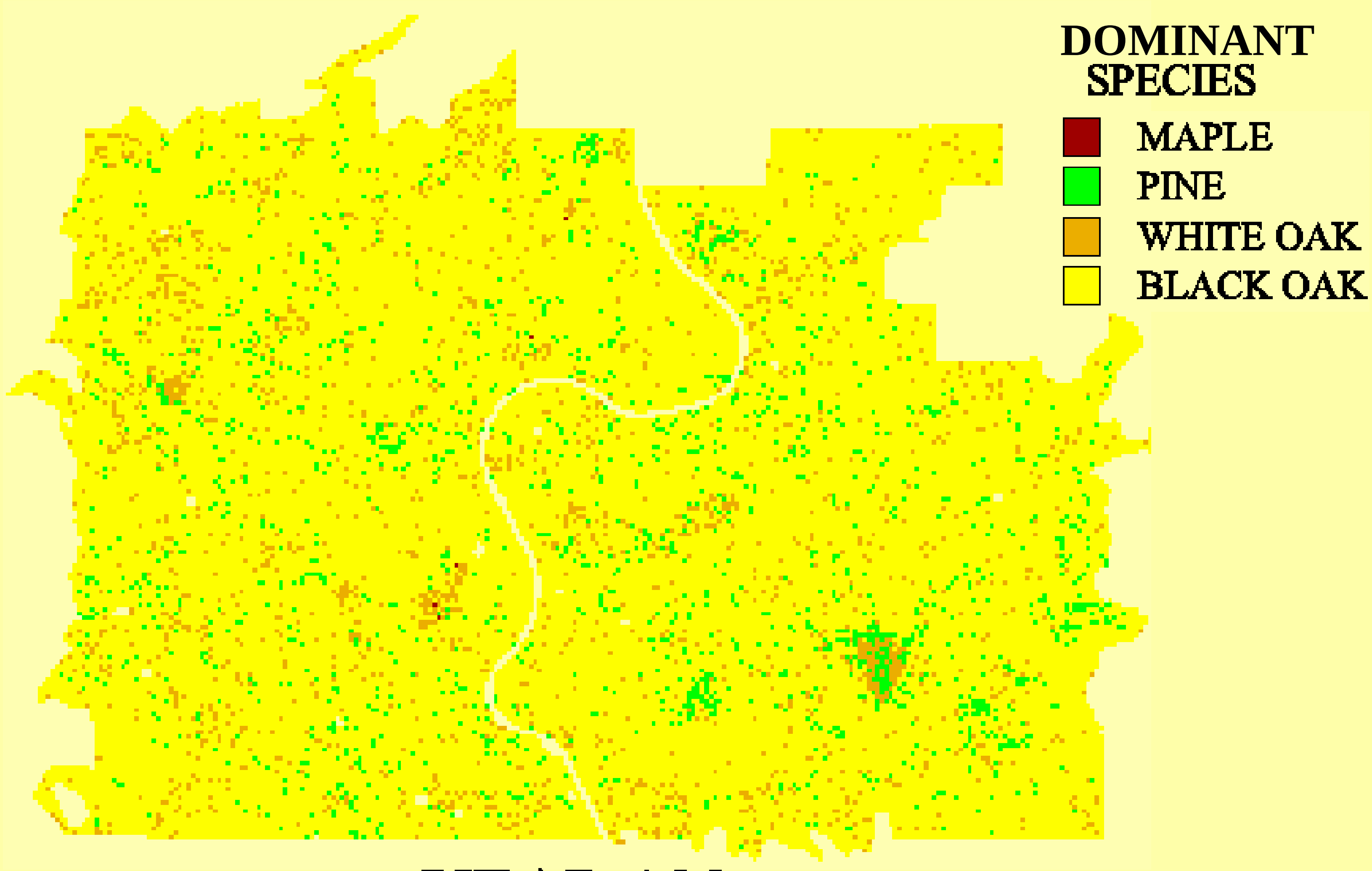
YEAR 100

NO HARVEST MANAGEMENT



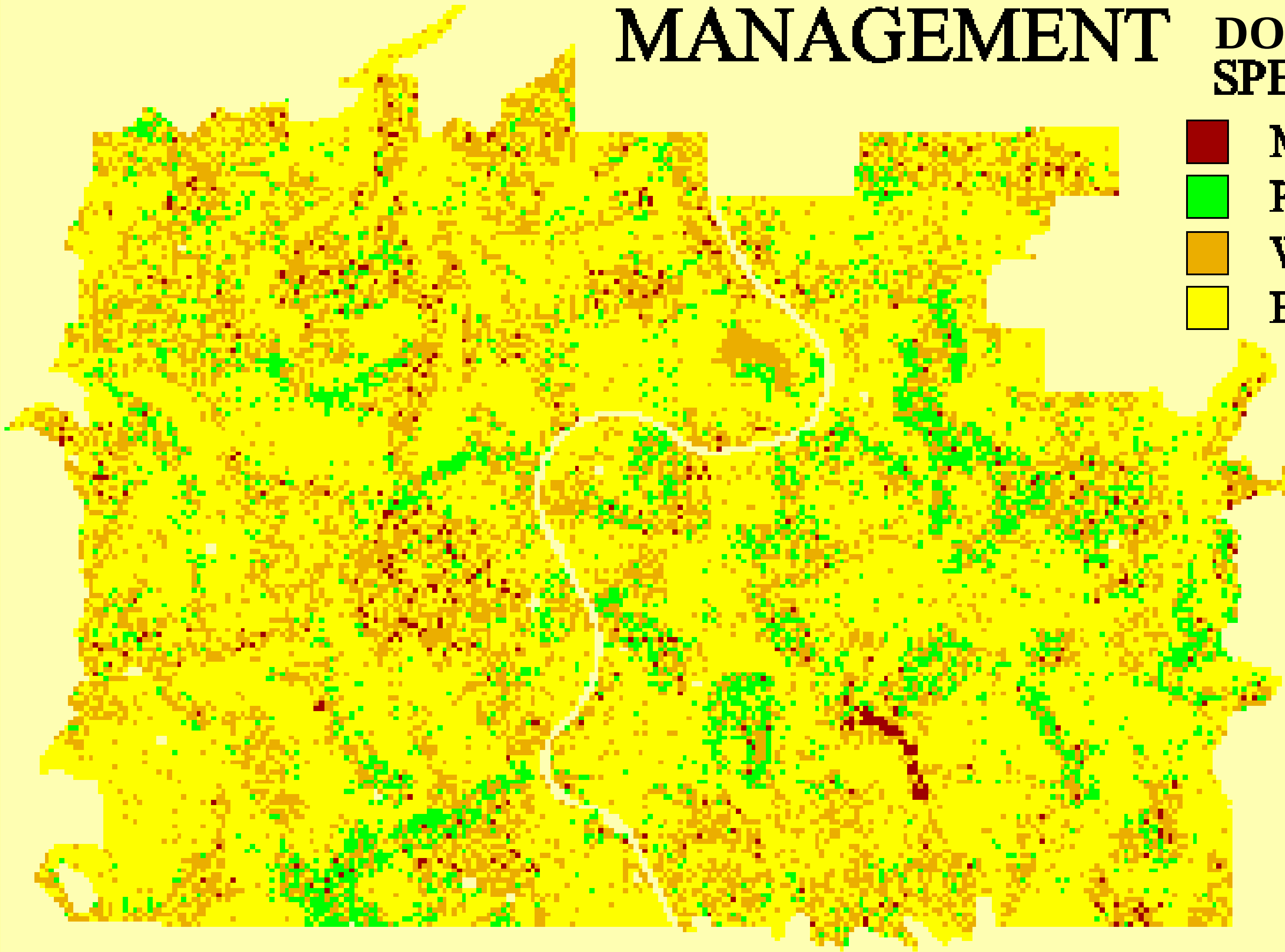
YEAR 100

EVEN-AGED INTENSIVE MANAGEMENT



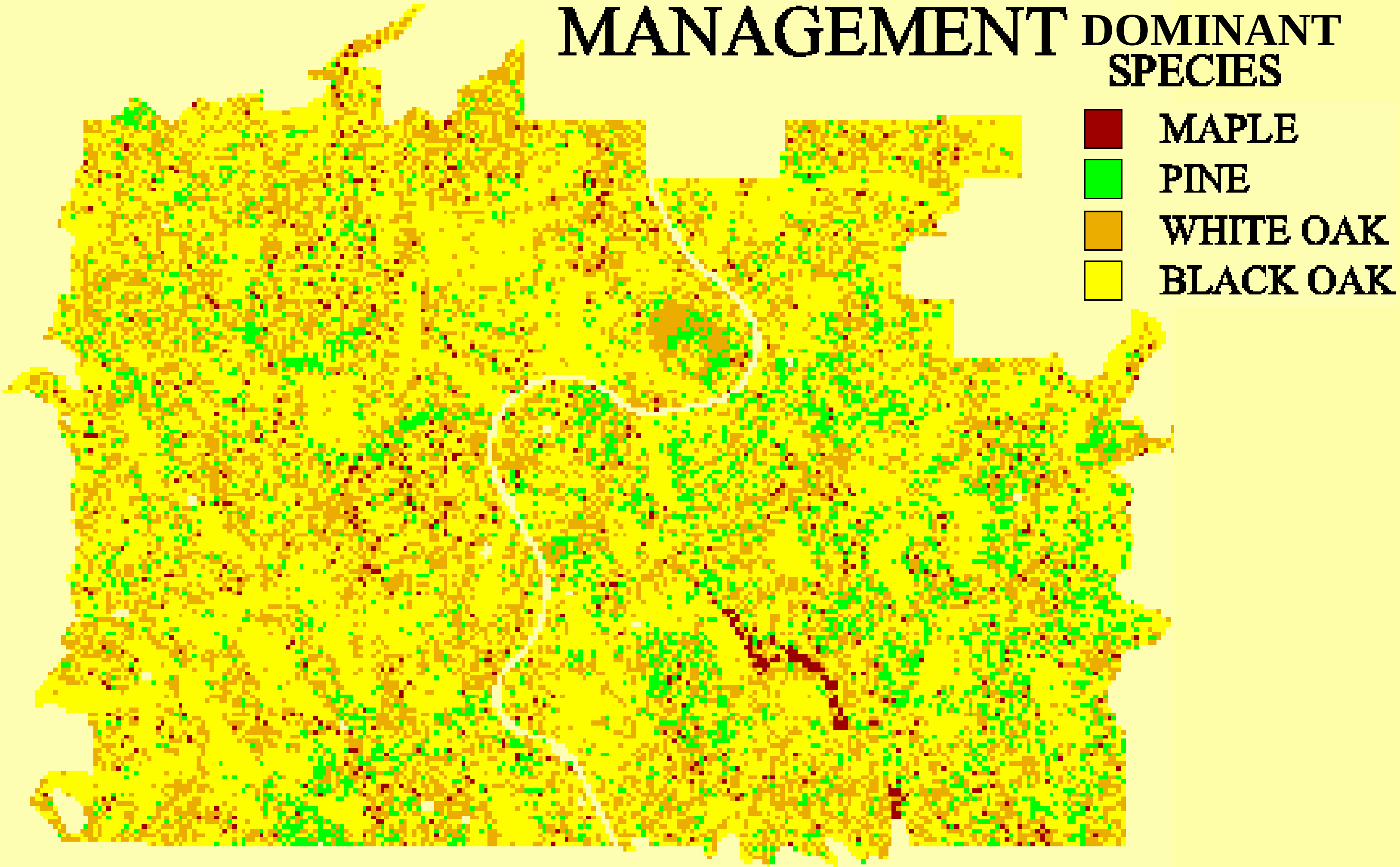
YEAR 100

EVEN-AGED LONG ROTATION MANAGEMENT



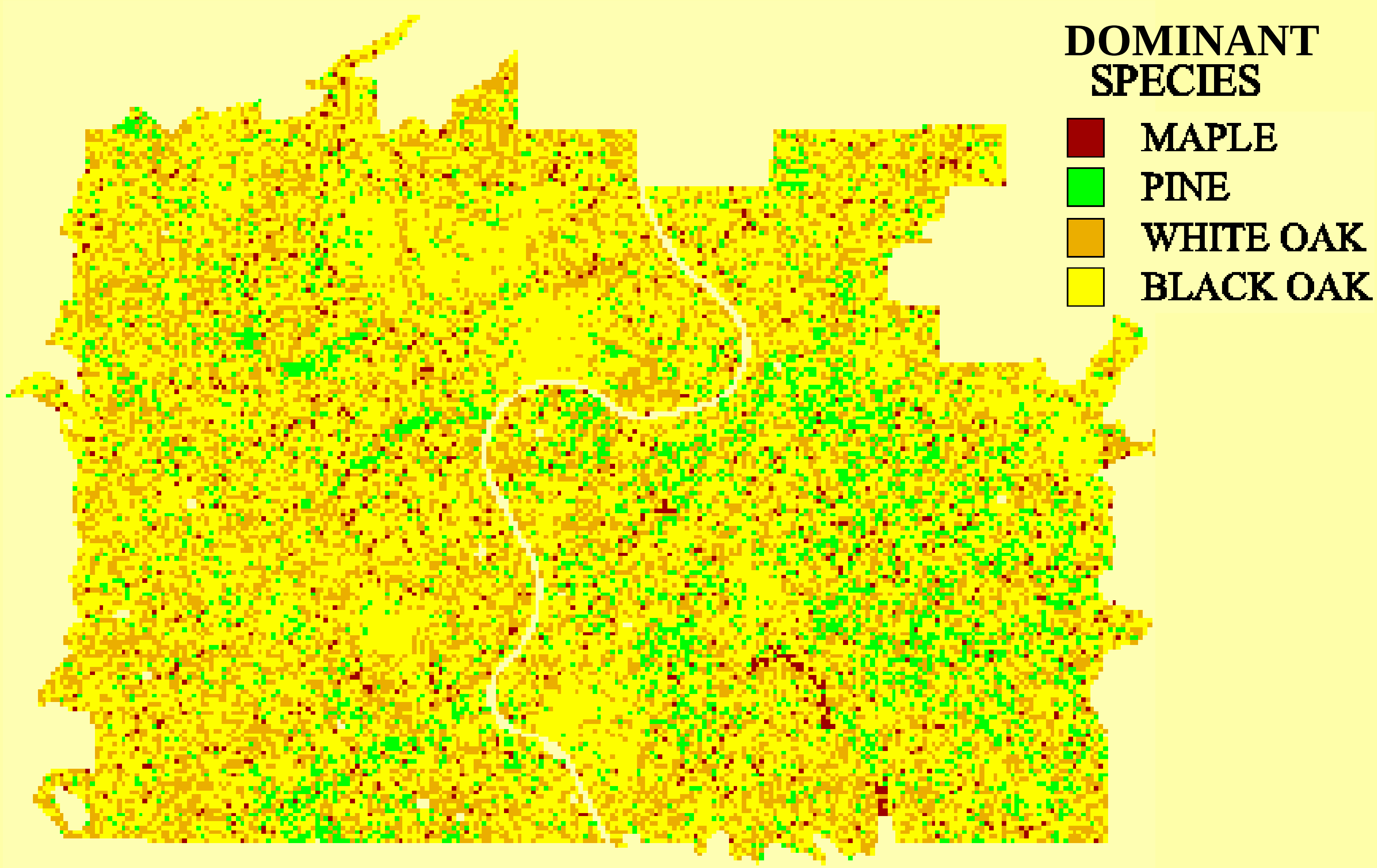
YEAR 100

EVEN-AGED & UNEVEN-AGED MANAGEMENT



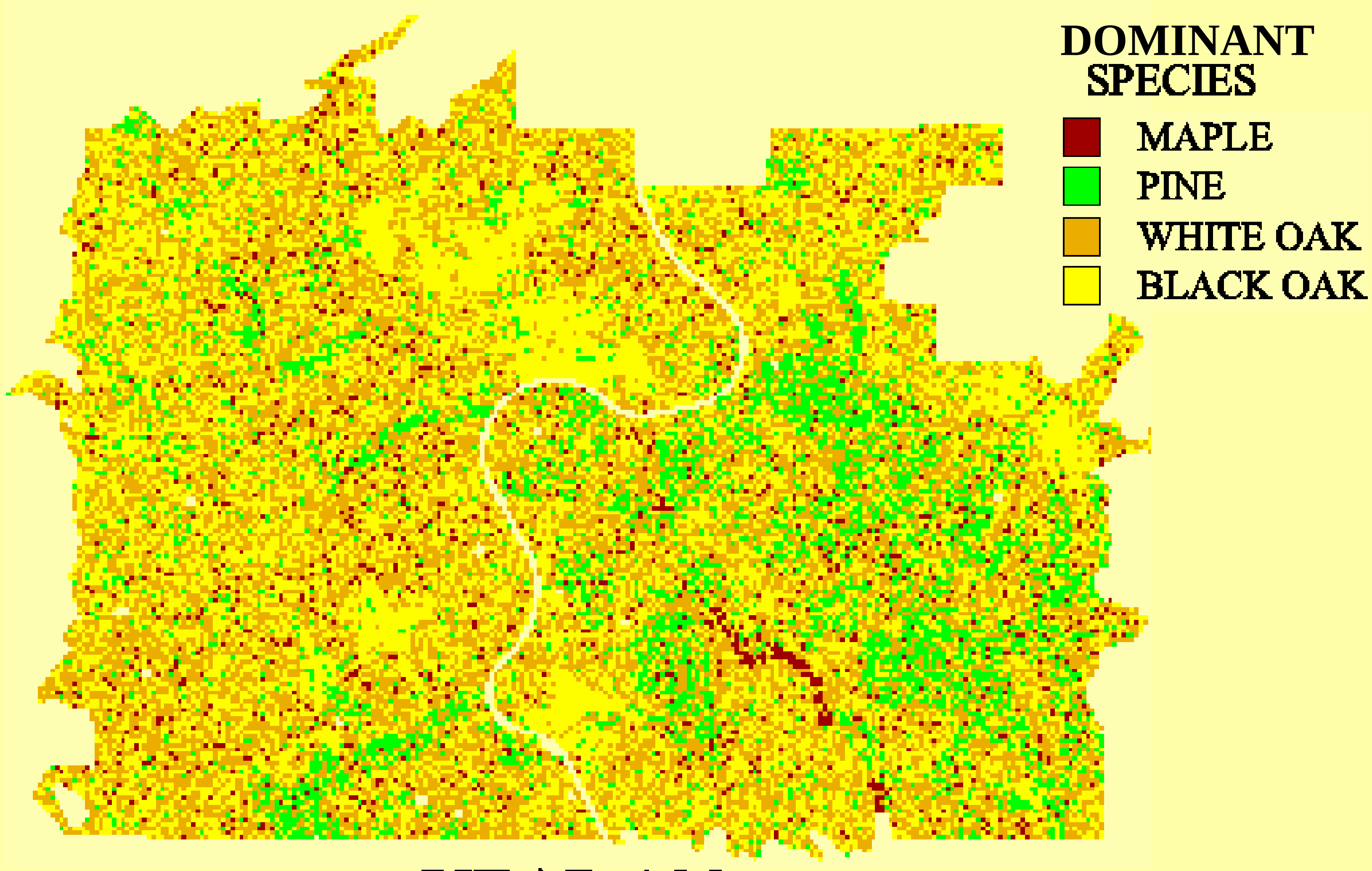
YEAR 100

UNEVEN-AGED MANAGEMENT



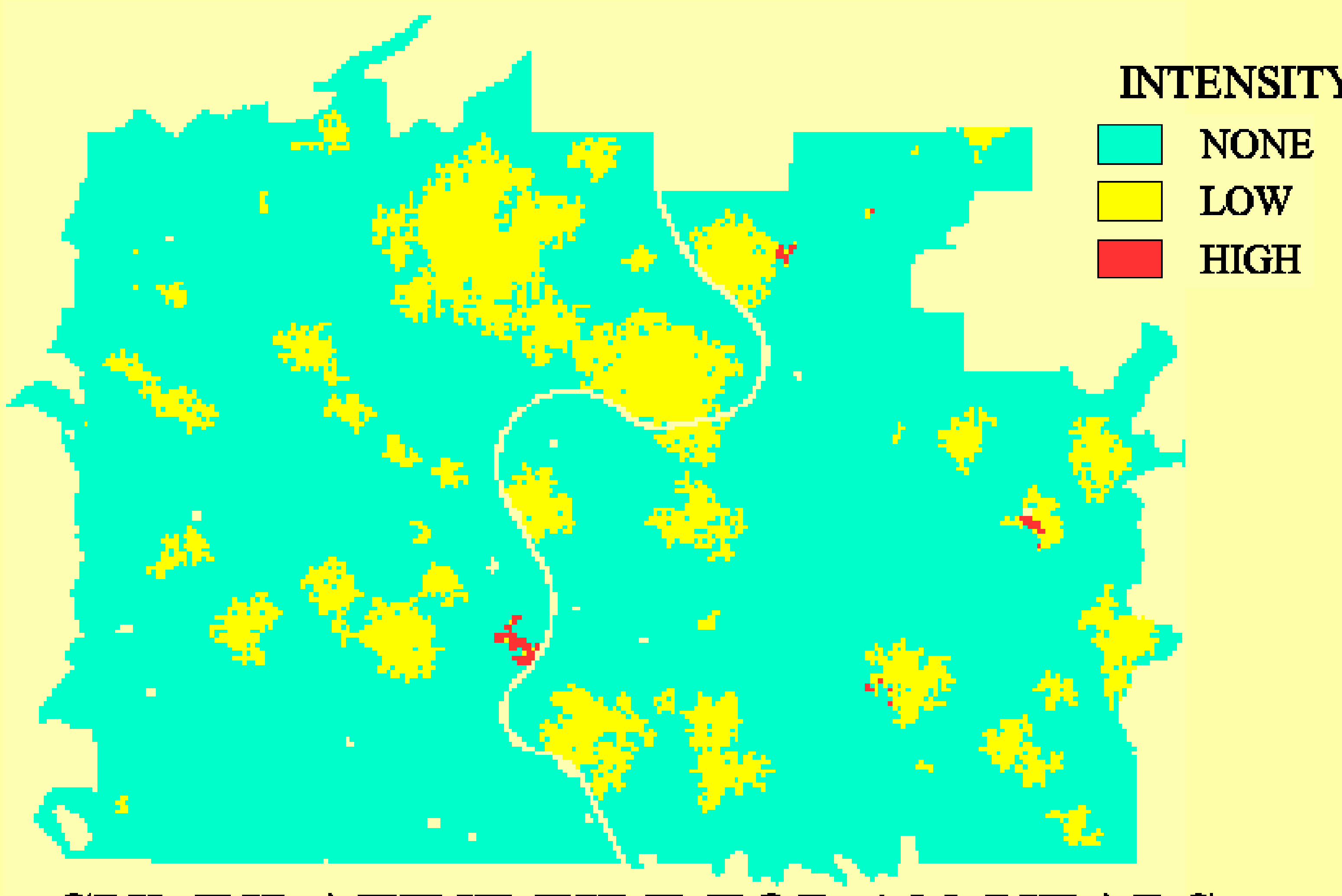
YEAR 100

NO HARVEST MANAGEMENT



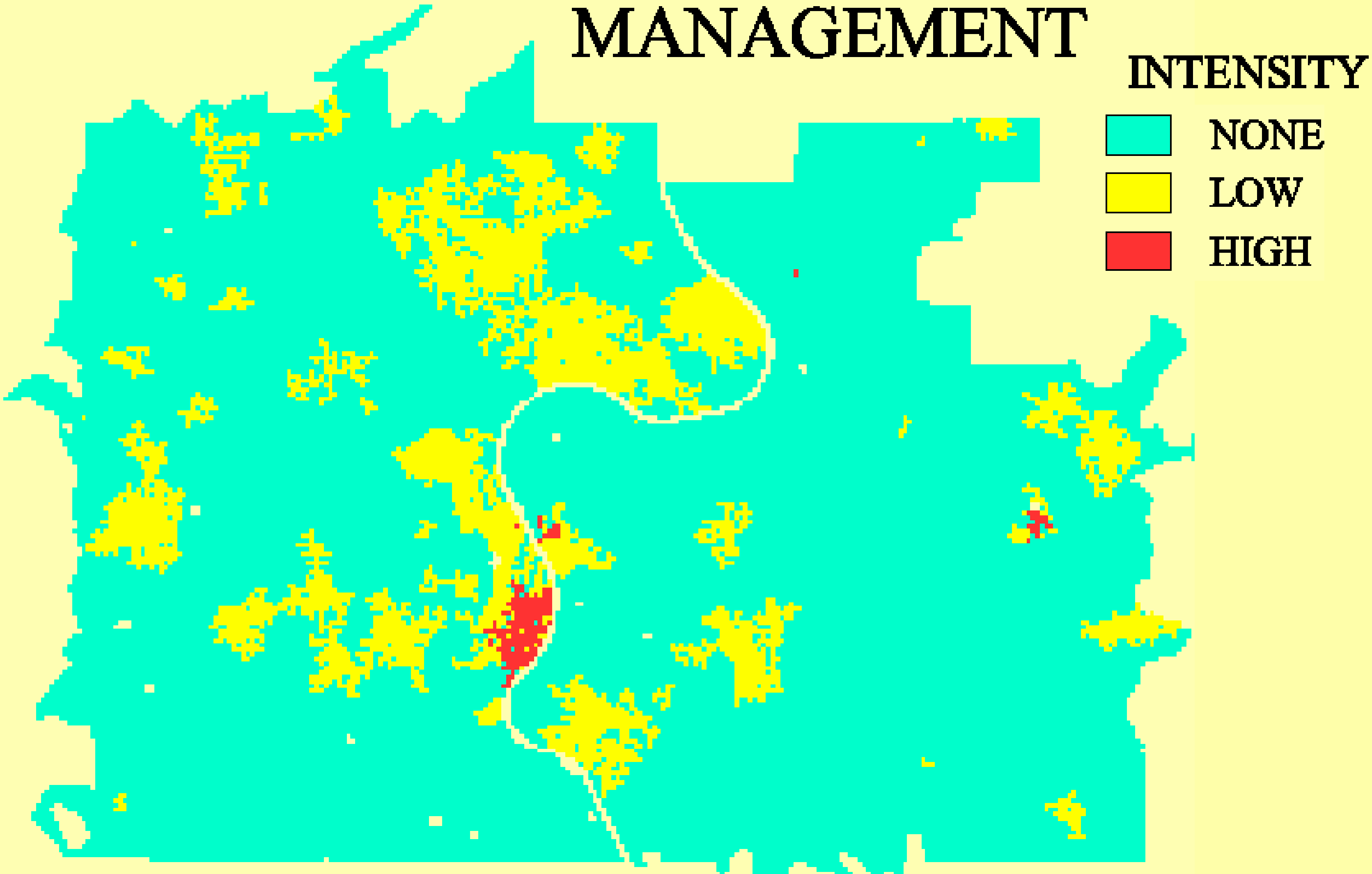
YEAR 100

EVEN-AGED INTENSIVE MANAGEMENT



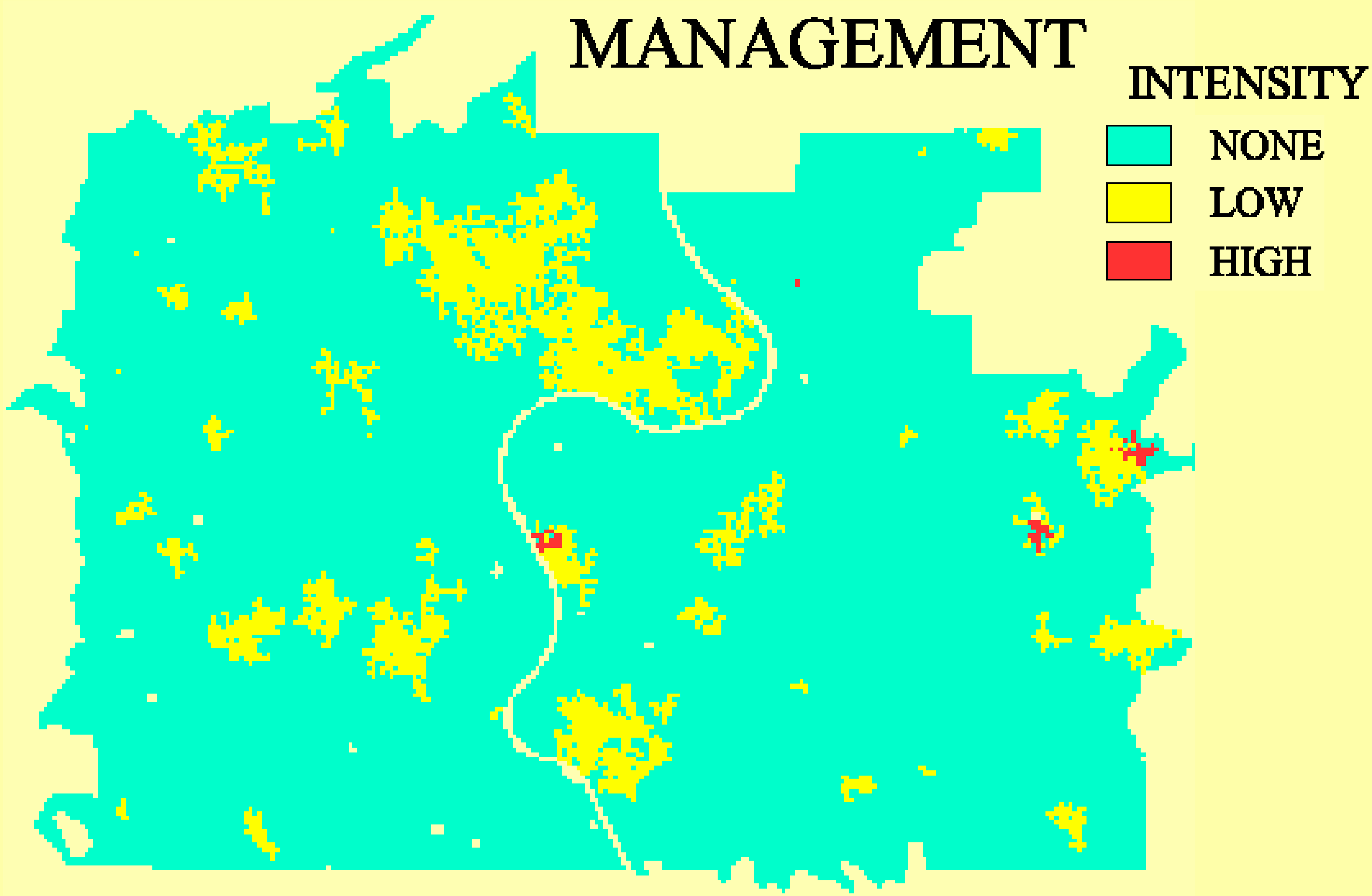
CUMULATIVE FIRE FOR 100 YEARS

EVEN-AGED LONG ROTATION MANAGEMENT



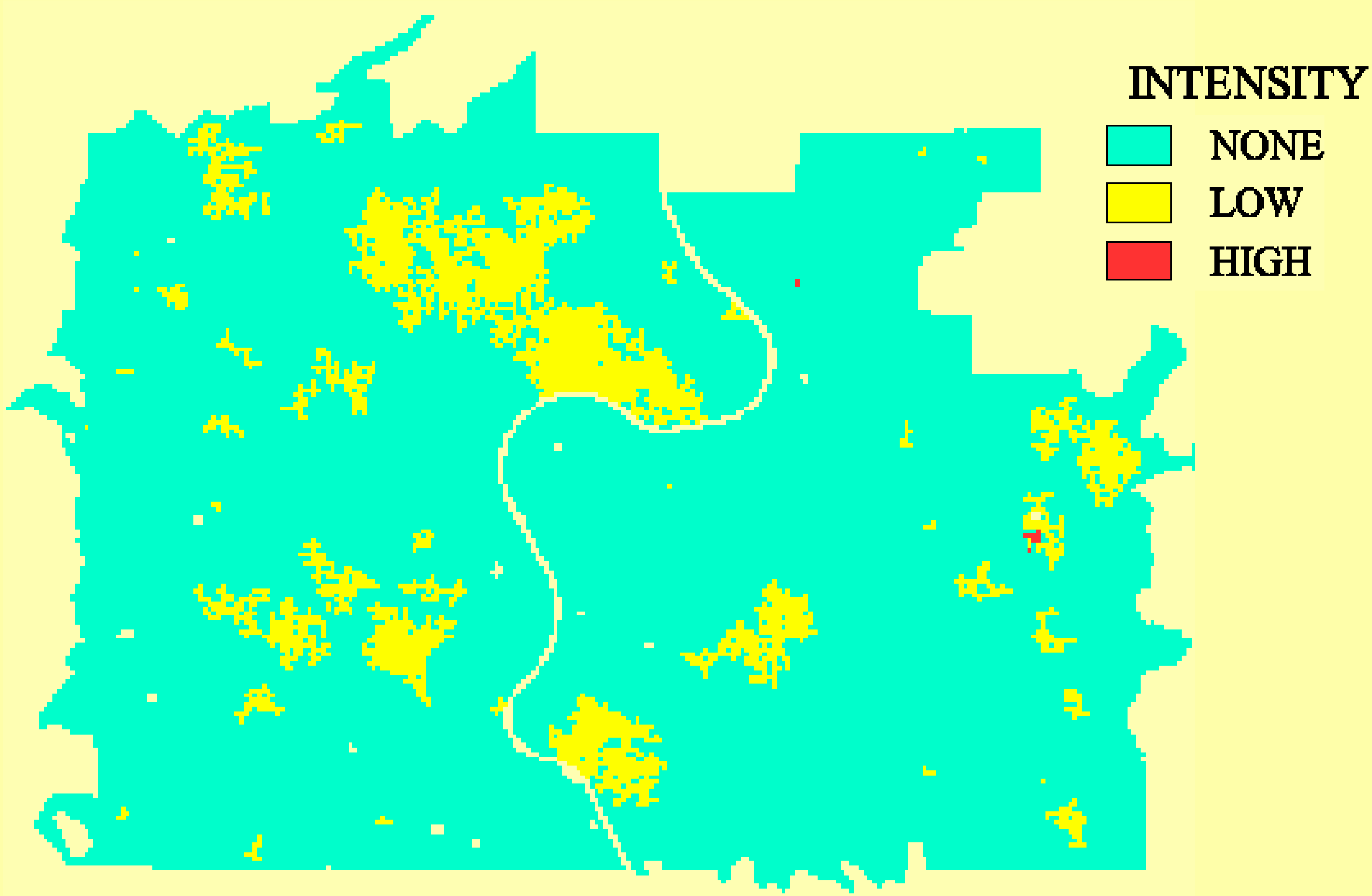
CUMULATIVE FIRE FOR 100 YEARS

EVEN-AGED & UNEVEN-AGED MANAGEMENT



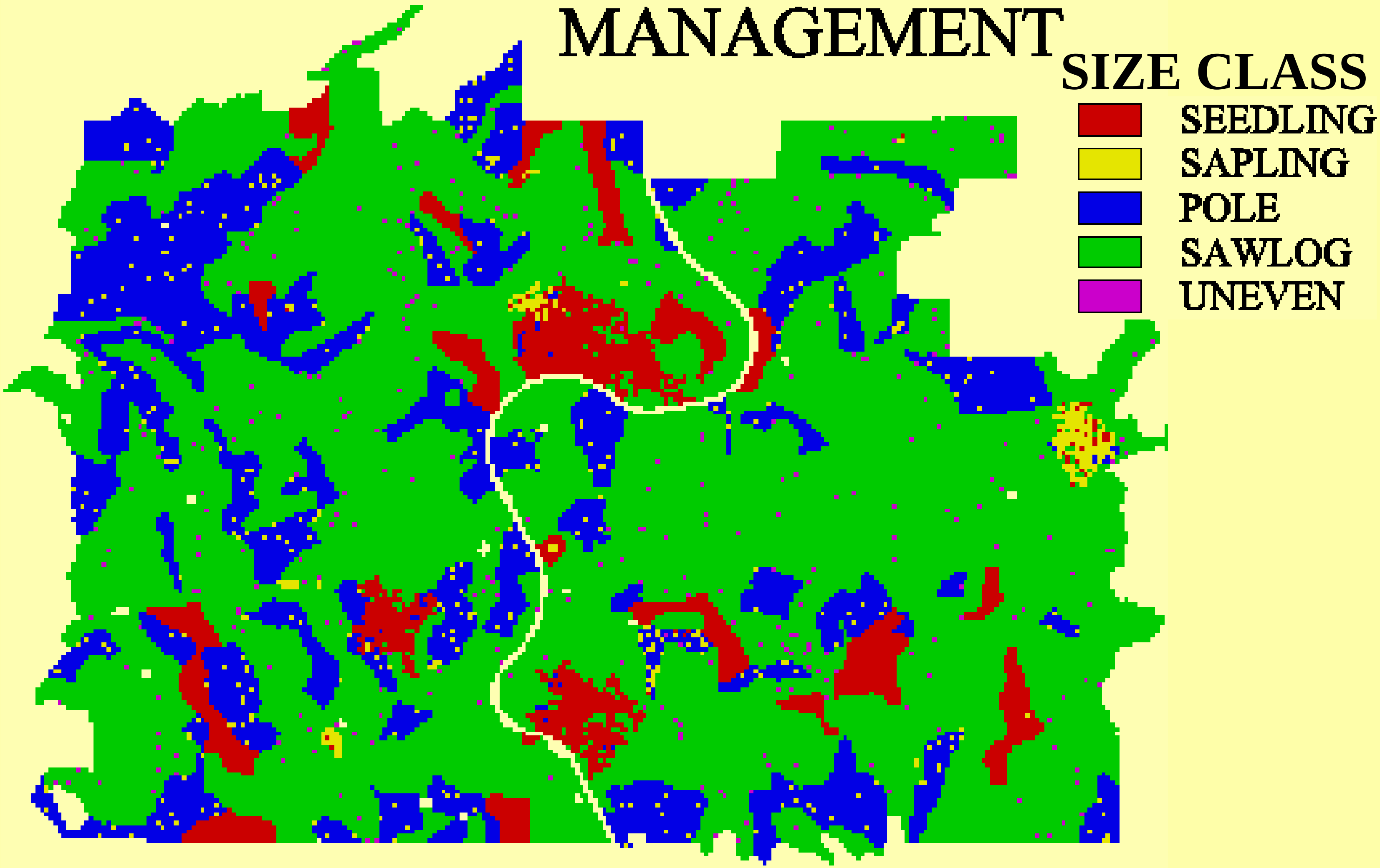
CUMULATIVE FIRE FOR 100 YEARS

UNEVEN-AGED MANAGEMENT



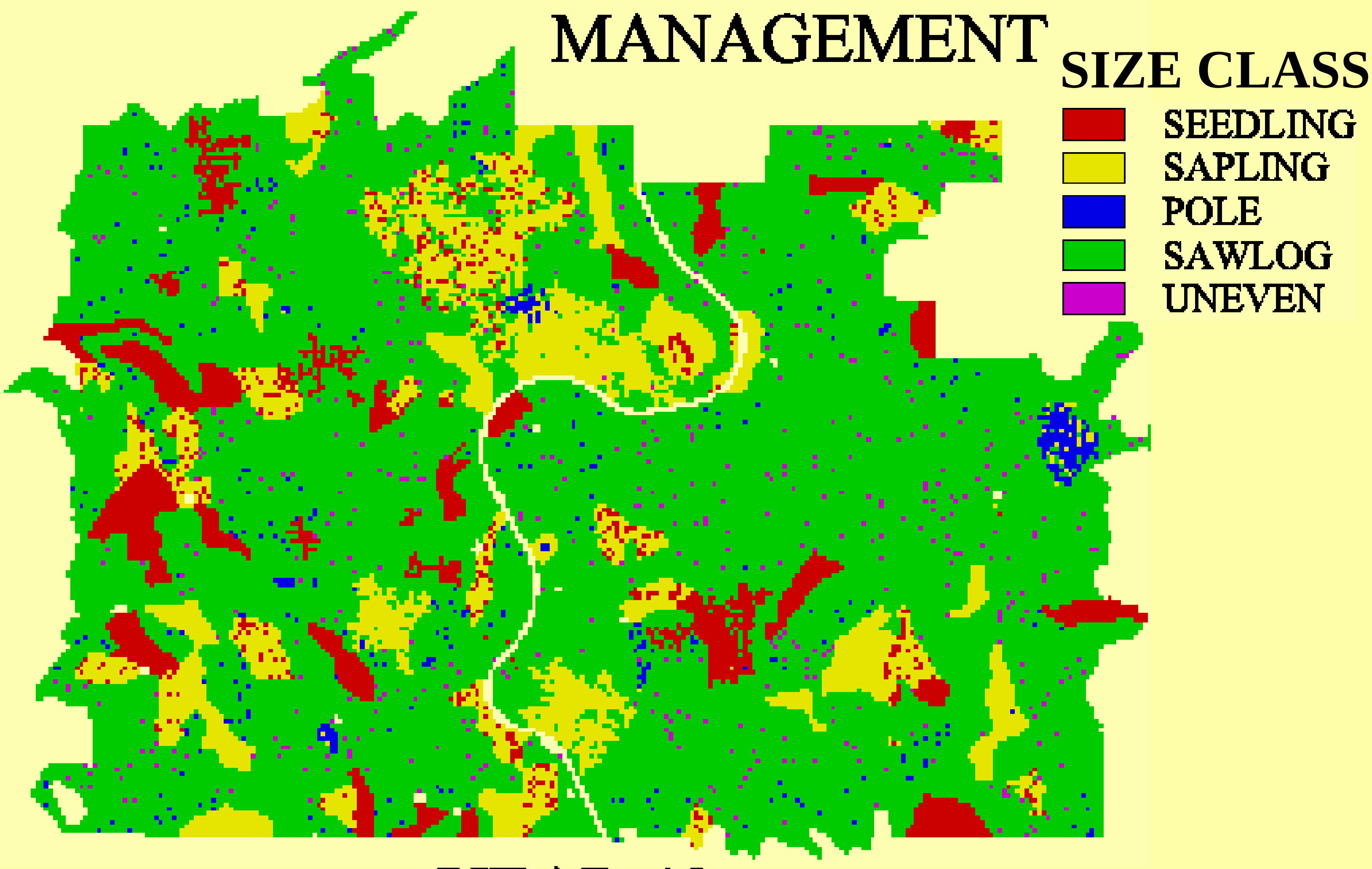
CUMULATIVE FIRE FOR 100 YEARS

EVEN-AGED LONG ROTATION MANAGEMENT



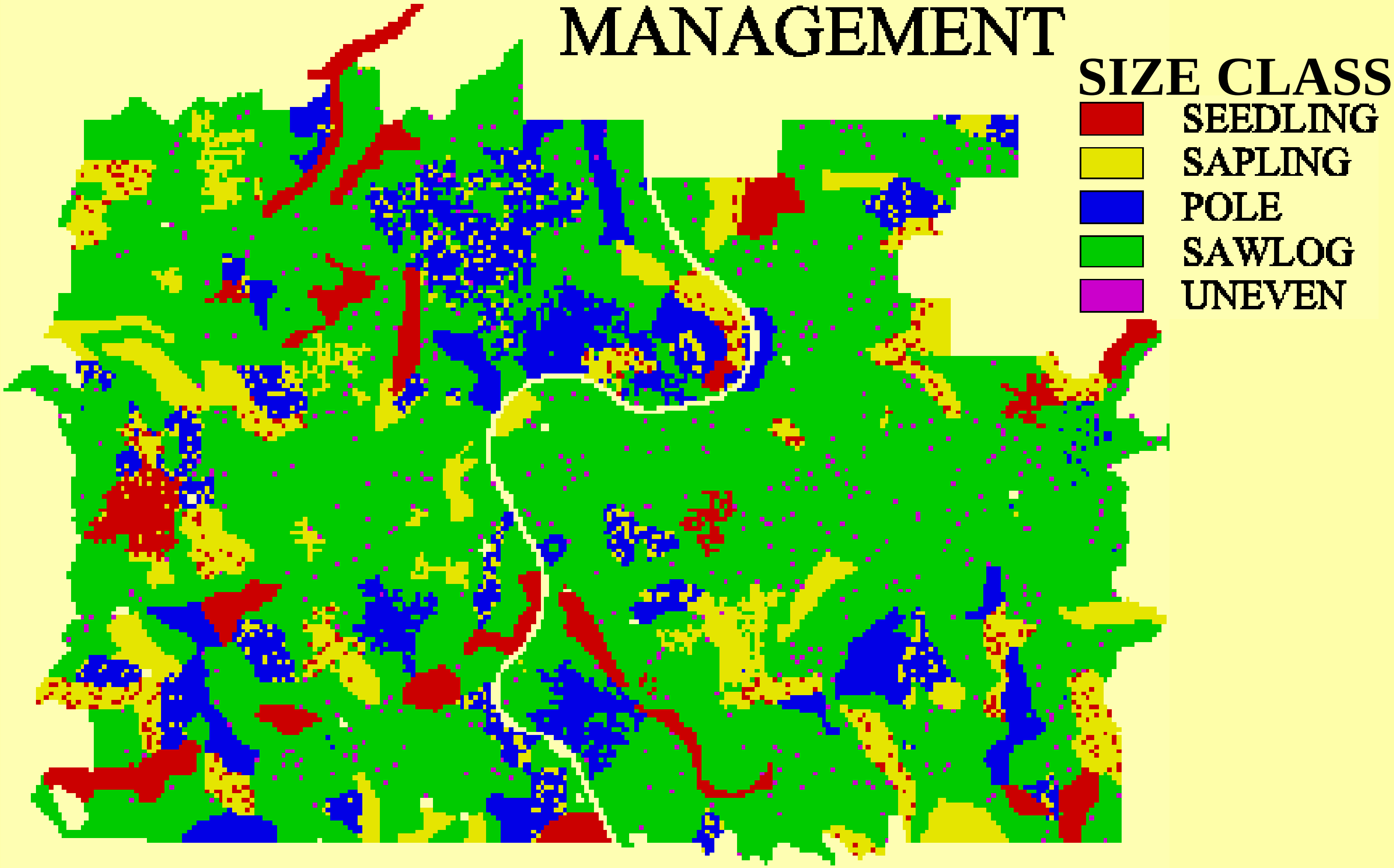
YEAR 20

EVEN-AGED LONG ROTATION MANAGEMENT



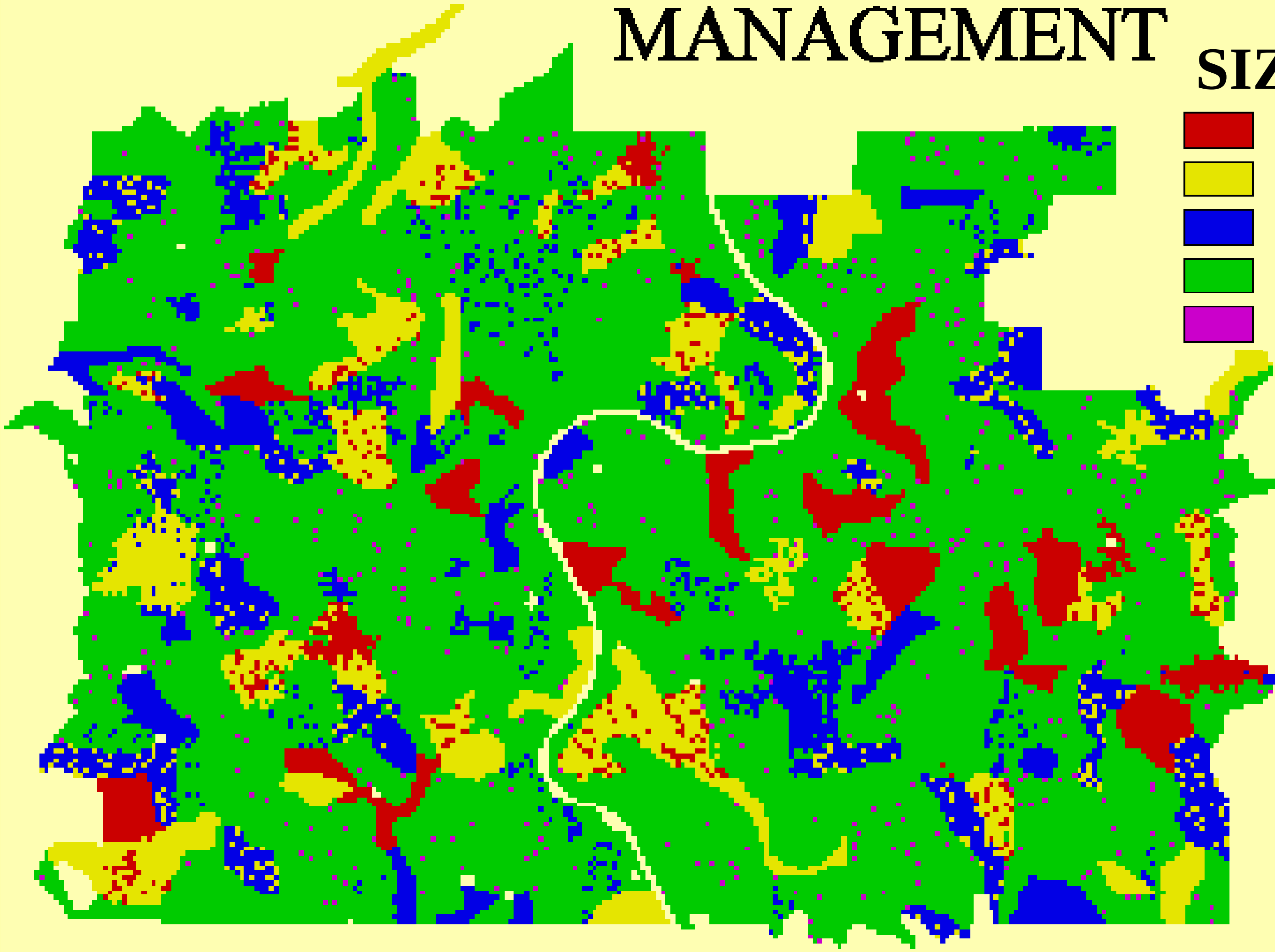
YEAR 40

EVEN-AGED LONG ROTATION MANAGEMENT



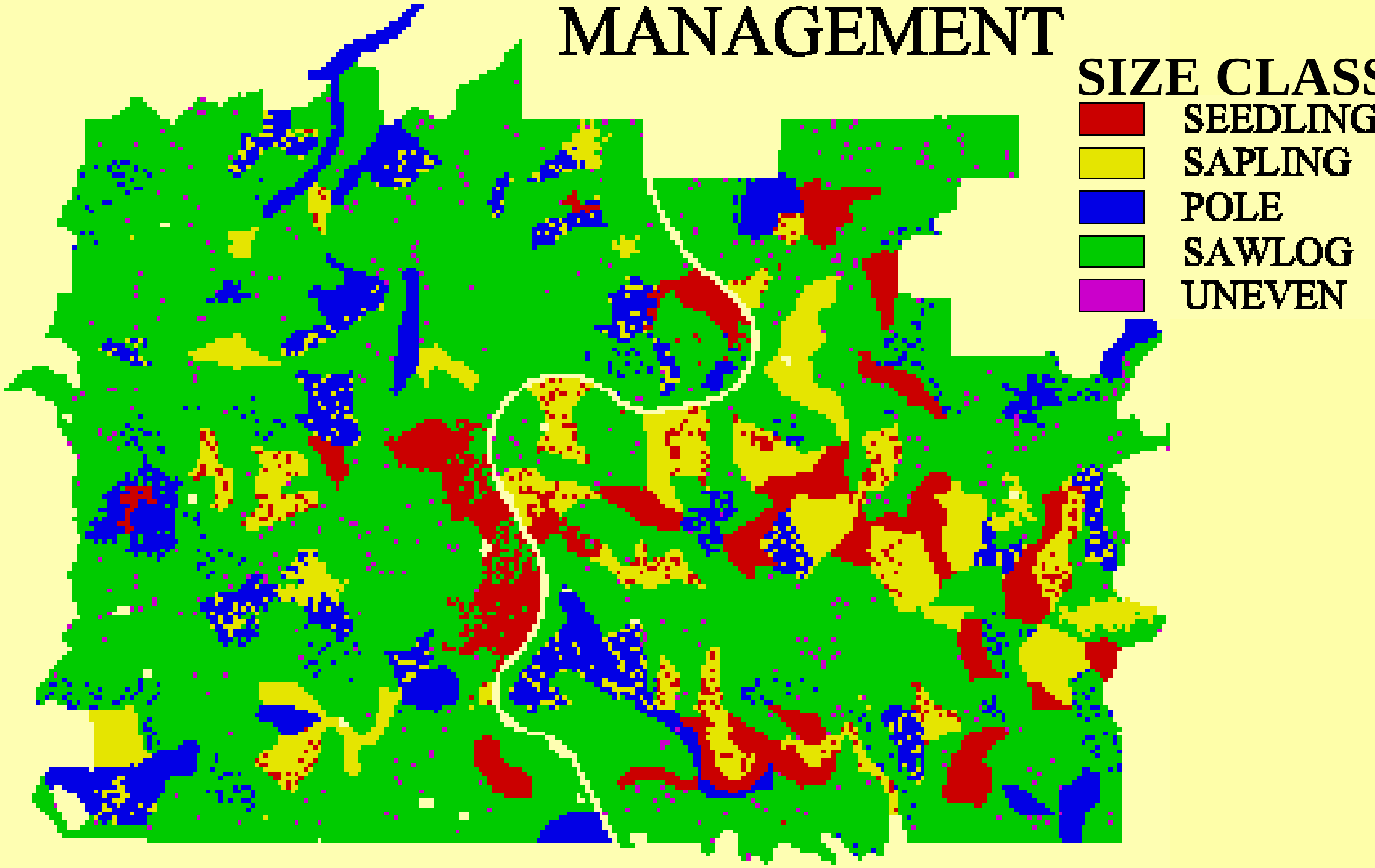
YEAR 60

EVEN-AGED LONG ROTATION MANAGEMENT



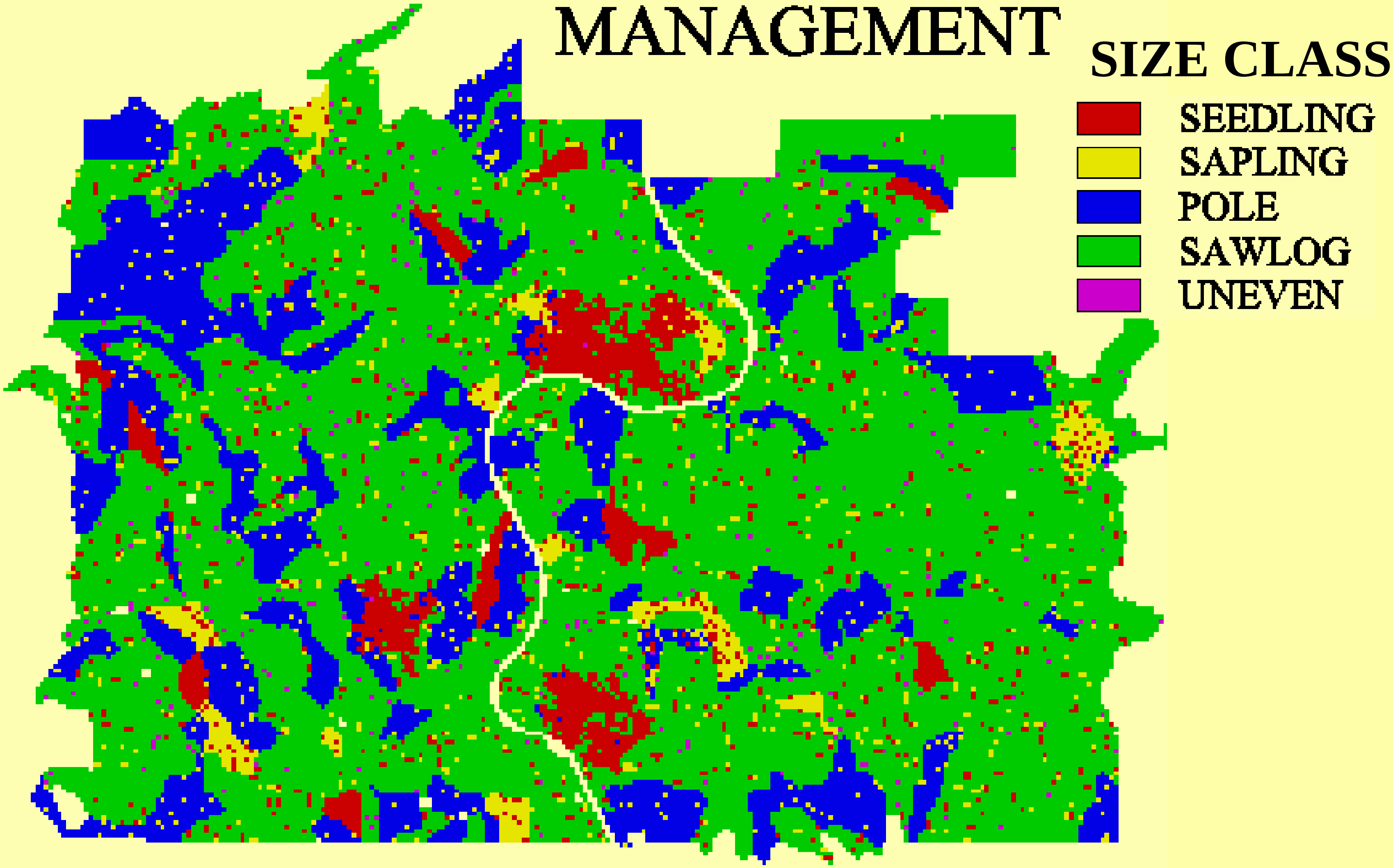
YEAR 80

EVEN-AGED LONG ROTATION MANAGEMENT



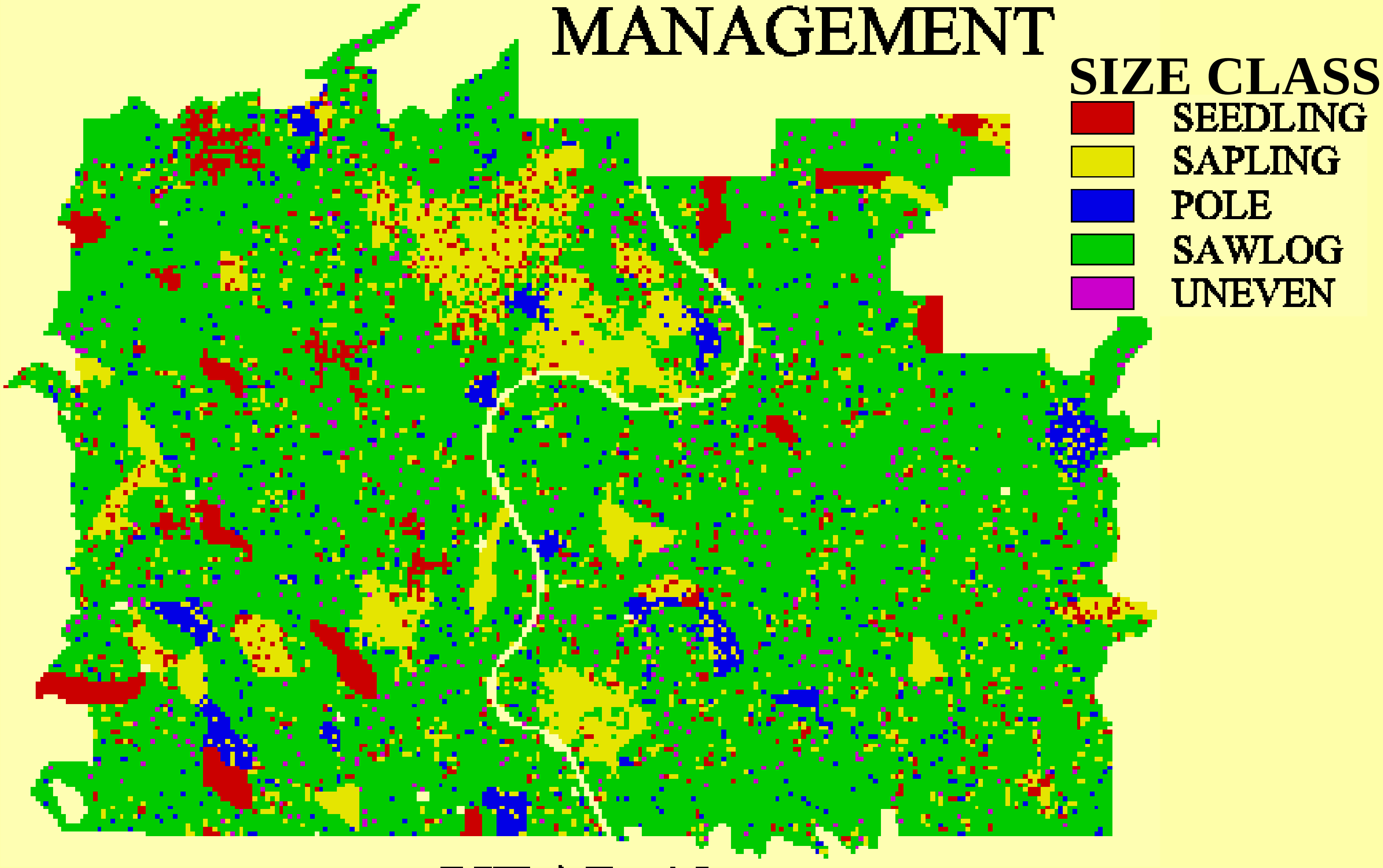
YEAR 100

EVEN-AGED & UNEVEN-AGED MANAGEMENT



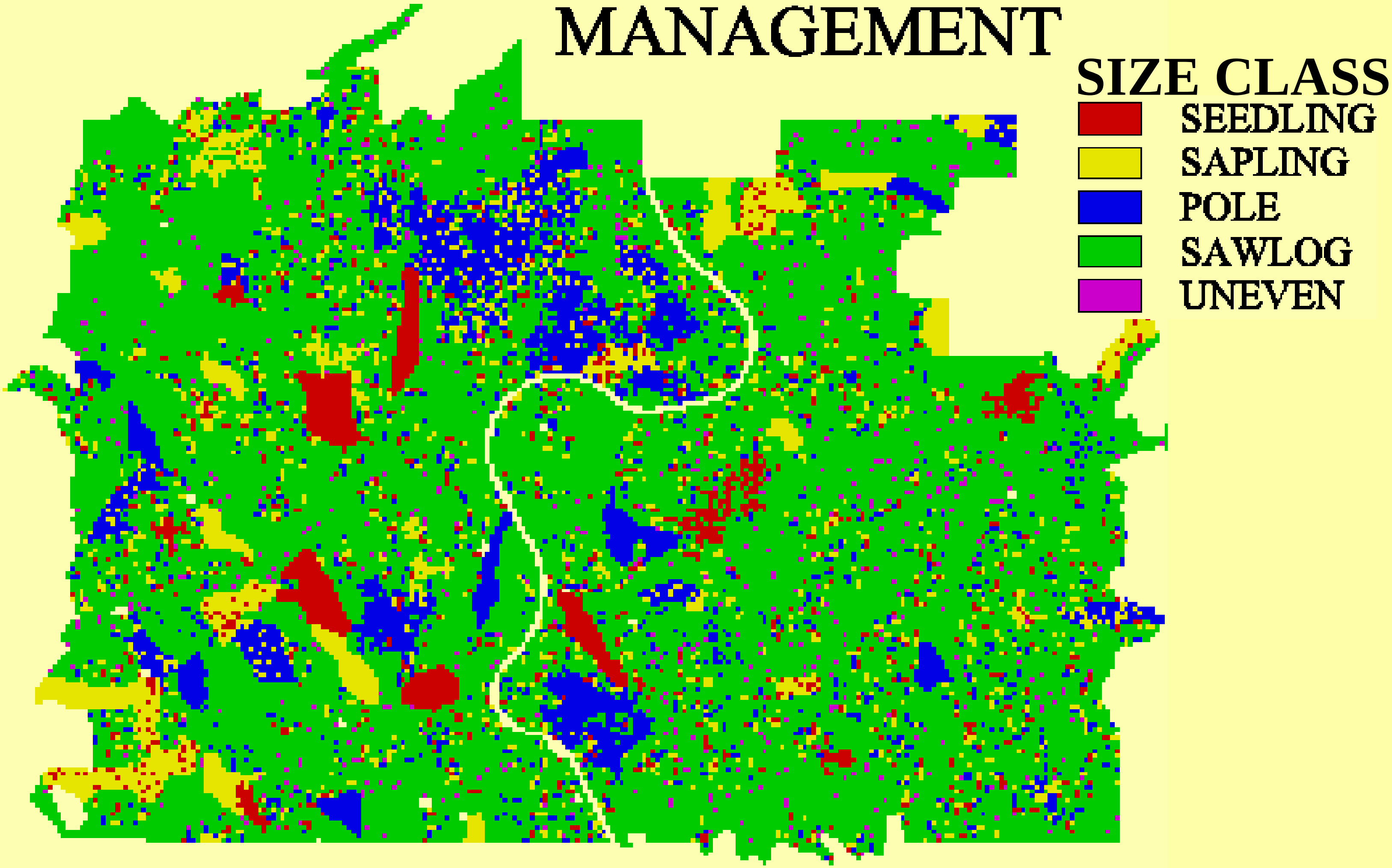
YEAR 20

EVEN-AGED & UNEVEN-AGED MANAGEMENT



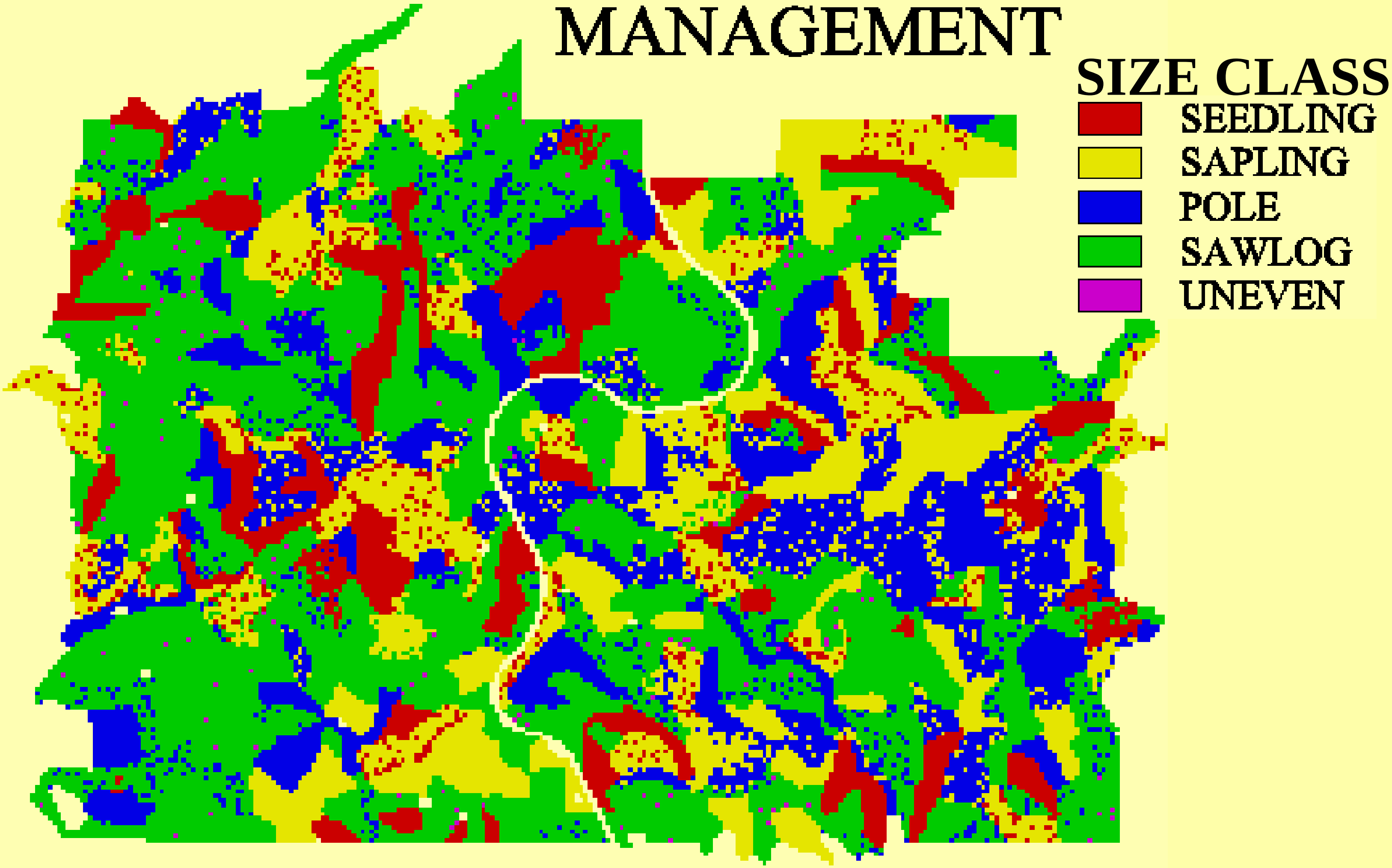
YEAR 40

EVEN-AGED & UNEVEN-AGED MANAGEMENT



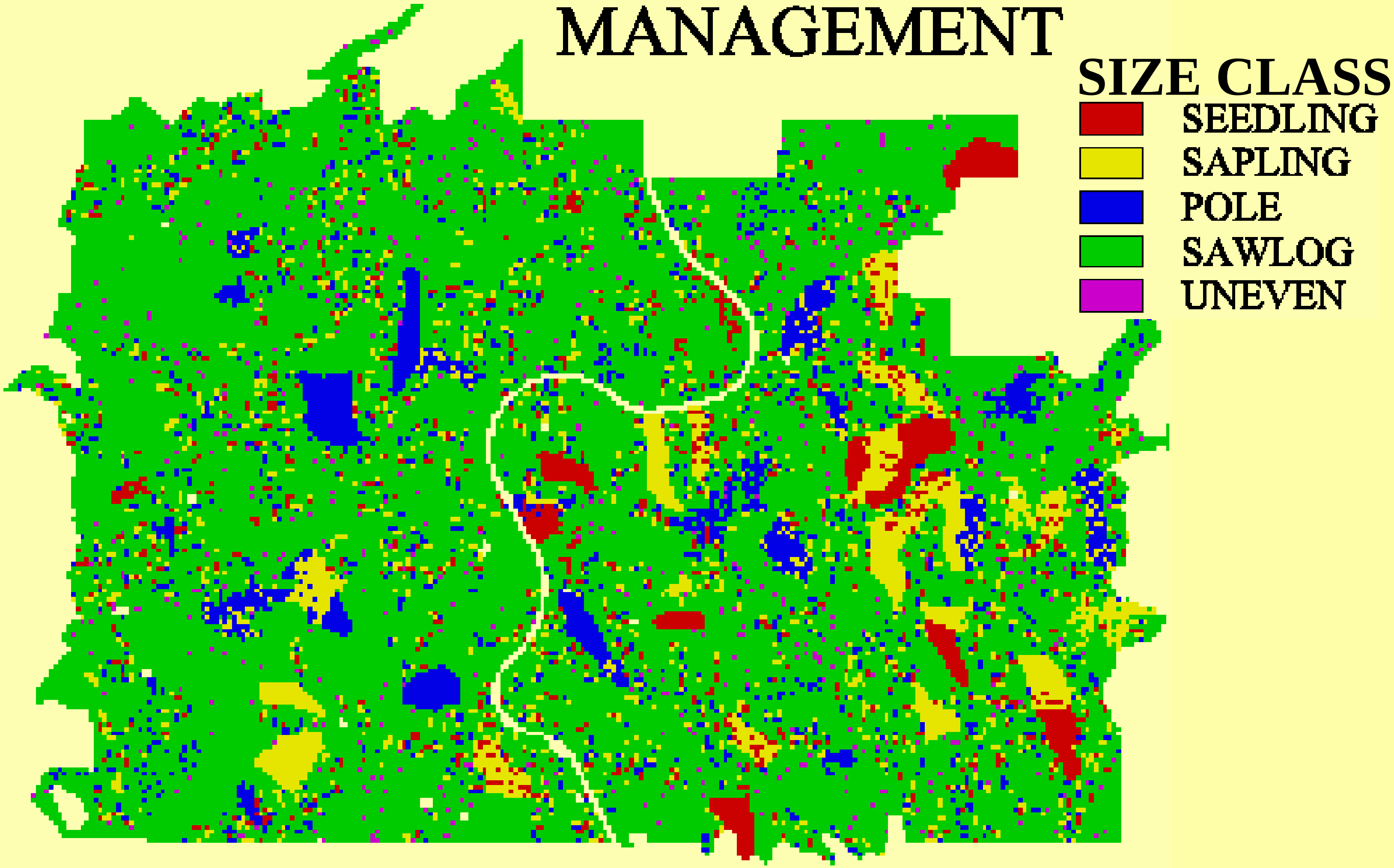
YEAR 60

EVEN-AGED & UNEVEN-AGED MANAGEMENT



YEAR 80

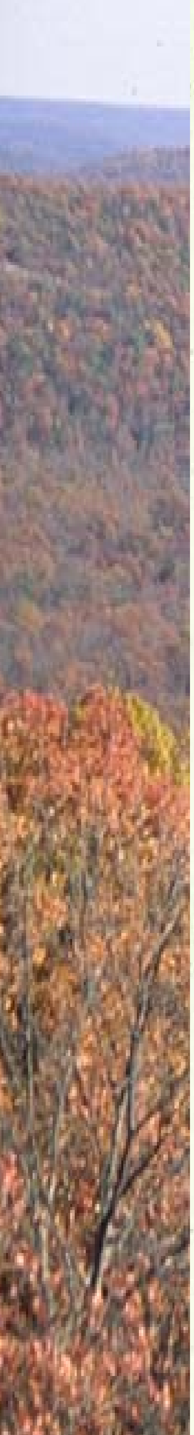
EVEN-AGED & UNEVEN-AGED MANAGEMENT



YEAR 100

Our Basic Modeling Assumptions

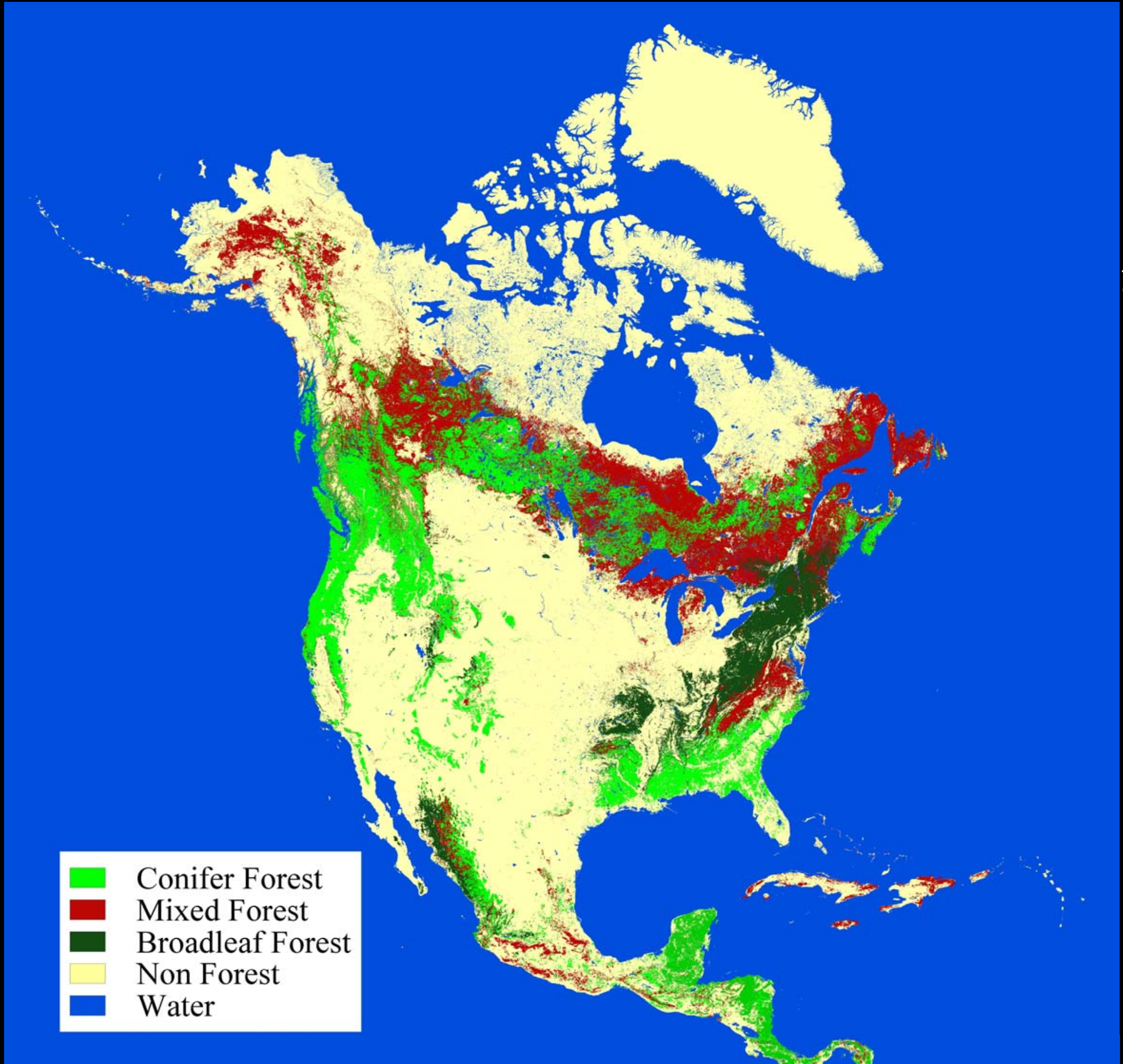
- Vegetation is constantly responding to (recovering from) disturbance.
- To some degree (and to a greater degree than most other ecosystem components), patterns of vegetation change are predictable.
- The landscape can be divided into ecologically similar units (ECS) that affect vegetation change.
- If we know (or can predict) the vegetation conditions across a landscape at some future point in time, we can say significant things about other ecosystem components.
- Requires a multi-disciplinary team



Simulating Effects of Timber Management, Wind, and Fire on Forest Landscapes to Guide Multiple-use Forest Planning

Stephen R. Shifley
Frank R. Thompson III
William D. Dijak

North Central Research Station
U.S. Department of Agriculture Forest Service
Columbia, Missouri



Source:
International Geosphere/Biosphere Program
http://www.igbp.kva.se/cgi-bin/php/frameset.php

Forest Cover

- 33% of Missouri is forested
- 30% of the North Central Region is forested
- 33% of the U.S is forested
- 31% of the North America is forested
- 30% of the World is forested